ERDC SR-07-2

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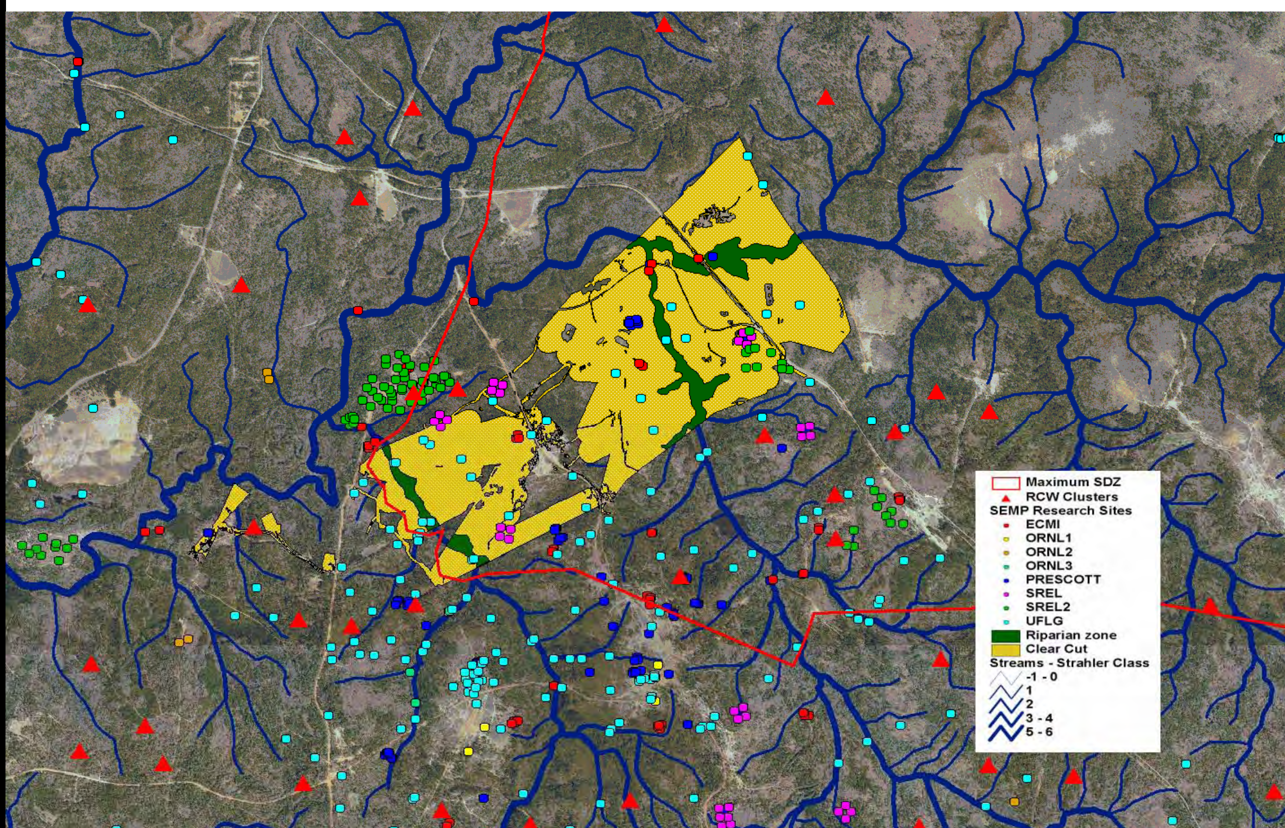
Engineer Research and Development Center

SERDP Ecosystem Management Project (SEMP)

2005 Annual Report

Compiled by Harold E. Balbach and Elizabeth L. Keane

March 2007



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Engineer Research and Development Center

Strategic Environmental Research and
Development Program

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SERDP Ecosystem Management Project (SEMP):

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Final report

Prepared for Strategic Environmental Research
and Development Program
Arlington, VA 22203-1821

Under Work Unit #SI-1114

DoD EPA DOE SERDP
Strategic Environmental Research and Development Program

Abstract: The SERDP Ecosystem Management Project (SEMP) was initiated in 1998 by the Strategic Environmental Research and Development Program (SERDP), after a 1997 workshop on Department of Defense ecosystem management challenges. After the workshop, SERDP allocated initial funding to a new project, titled the SERDP Ecosystem Management Project, designated as CS-1114, which changed in mid-2005 to SI-1114. This report records the many changes that occurred in the SEMP Project in the year 2005. All the original SEMP research projects have completed their funded work and final reports were received during this year. As reported in the 2004 SEMP Annual Report, significant change took place in almost every aspect of SEMP program management and execution during 2005. The response to the comprehensive external review of SEMP is reported as these changes have been implemented. New SEMP research projects are no longer being funded within the SEMP budget, but will be separate Statements of Need through the normal SERDP process. Two workshops were held at Fort Benning in January and February 2005 to identify more critical installation needs; Fort Benning staff, SEMP researchers, TAC members, and several outside experts reviewed these results, which resulted in a redefined research plan for 2006 and beyond.

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Preface

This study was conducted for the Strategic Environmental Research and Development Program (SERDP) Office under SERDP Work Unit CS (later SI)-1114, “SERDP Ecosystem Management Program (SEMP).” The technical monitor at the time of the activities included in this report was Dr. Robert W. Holst, Program Manager. The Executive Director of SERDP is Mr. Bradley P. Smith.

The work was completed under the direction of the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL), Engineer Research and Development Center (ERDC). The SEMP Project Director through August, 2005 was Mr. Bill Goran, who was succeeded by Mr. Lee Mulkey, of the University of Georgia. The CERL Principal Investigator was Dr. Harold E. Balbach. William Goran is the ERDC-CERL Strategic Program Planner. Alan B. Anderson is Chief, CEERD-CN-N, and John Bandy is Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Director of CERL was Dr. Ilker Adiguzel.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. James R. Houston was Director.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
Feet	0.3048	meters
hectares	1.0 E+04	square meters
horsepower (550 foot-pounds force per second)	745.6999	watts
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
pounds (mass)	0.45359237	kilograms
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

1 Introduction

The year 2005 was one of major changes in the SERDP Environmental Management Program. All the original SEMP research projects, whether from the Indicators area funded in FY1999 or the Thresholds area funded in FY2000, completed their funded work by CY 2004 or 2005, and final reports were received during this year. The Executive Summaries of the five final reports appear here in Chapters 4 through 8. This represents the close-out for these projects. Each of them also presented a “Final Report” poster at the November 2005 SERDP Partners in Technology Symposium in Washington, DC (Chapter 3).

Reported as planned actions in the 2004 SEMP Annual Report (ERDC SR-06-1), significant change took place in almost every aspect of SEMP program management and execution during 2005 (Chapter 2). At the request of the Scientific Advisory Board, and after consultation with the SEMP Program Manager, the SERDP Program Office, and the SEMP Technical Advisory Council, a decision was made in late 2003 to contract with an external organization to conduct a comprehensive review of SEMP. The final version of the evaluation report was completed in November 2004. In summary, it was recommended that the SEMP project be continued, but restructured; 2005 was the year these changes were implemented. Chapter 2 presents an overview of the recommendations and the actual and proposed responses to them.

Another major structural change, which was implemented in 2005, is that new SEMP research projects are no longer be funded within the SEMP budget. They will be the results of responses to separate Statements of Need through the normal SERDP process, and will be coordinated with the SEMP project manager, but not controlled by him/her. The first of these “new” projects was included in the November 2004 announcements by SERDP as CS-SON 05-03, and was entitled “Developing Terrestrial Biogeochemical Cycle Models for Fort Benning Ecosystems.” The successful proposer, the USGS EROS Data Center, was directly funded and performs its own reporting and financial management processes outside the SEMP process as project SI-1462. This was funded in June, 2005 (Appendix C). The SEMP project manager is, however, involved in supporting the U.S. Geological Service research team with respect to assistance in data acquisition and coordination with Fort Benning personnel and with the SEMP-supported staff on site at Fort Benning. It is anticipated that future SONs related to additional SEMP-related topics will be managed in this same manner. The second of these new projects was included in November 2005, and was entitled WATERSHED MANAGEMENT MODELS FOR MILITARY INSTALLATIONS: FORT BENNING WATERSHEDS, identified as SON NUMBER: SISON-07-04. This SON is reproduced here in Appendix D. Proposals against it are in the final review process at the time this report is being prepared.

Perhaps the greatest single changes of direction, which was introduced in 2005, represents the response to SAB, TAC, and RAND suggestions that the SEMP focus be more directly on needs of Fort Benning land managers. In a sense, this represents an almost total reversal of philosophy. One might have referred to the original SEMP focus as being one of studying the ecosystem characteristics, following the guidance from the organizing workshop,[1] with the hope that the principles discovered would prove of value in land management on a military installation. The new process would be to identify land management needs, and design research and studies to assist the installation in problem solutions that would have immediate application within existing processes. A workshop was held among Fort Benning land management personnel in January 2005 to identify such needs, and was followed by a SEMP workshop in February, 2005, where a mix of Fort Benning staff, SEMP researchers, TAC members, and several outside experts reviewed these results (Chapter 3). The follow-on recommendations, as discussed in Chapter 2, focused on two areas of need: forest health and water quality management. It is expected that future SONs and study proposals will focus on these mutually-agreed topic areas.

A realignment of research structure was implemented by the SERDP Program Office in mid-2005, which caused the area within which SEMP falls to be designated the Sustainable Infrastructure area. The prefix SI thus replaced CS as the topic area for project 1114, which is now referred to as SI-1114. In the chapters that follow however, those projects that were completed before the change are still referred to as being part of CS-1114.

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[1] Botkin, B.D., P Megonigal, N. Sampson, Summary Report: Management-Scale Ecosystem Research Workshop, unpublished report to SERDP Program Office, 1997.

2 Management Plan for SEMP September 1, 2005

Mr. Lee Mulkey, University of Georgia – Savannah River Ecology Laboratory - Director of SEMP

The numbering of the sections in this chapter refers to the sections of the Management Plan as prepared for and presented to the Scientific Advisory Board in September 2005.

1.0 Introduction

The SERDP Ecosystem Management Program's (SEMP) mission is to support the development of ecosystem science and technology to improve ecosystem management at military installations. Its goals since inception have been:

- to establish one or more sites on DoD facilities for long-term ecosystem monitoring, and
- to pursue ecosystem research activities relevant to sustaining DoD mission capabilities.

SEMP was initiated as a result of the 1997 SERDP Ecosystem Workshop.[1] The Workshop identified at that time some of the critical knowledge gaps in understanding ecosystem status, especially as the gaps relate to military land management concerns. The primary themes that emerged from the workshop included (1) Ecosystem Health or Change Indicators; (2) Thresholds of Disturbance; (3) Biogeochemical Cycles and Processes; and (4) Ecosystem Processes as they relate to multiple temporal and spatial scales. Since its inception, SEMP has committed to working at the Fort Benning installation in southwest Georgia.

SEMP has now been in operation for over 5 years. A number of internal and external reviews have identified both strategic and management opportunities for significantly improving the quality and breath of the research program, its relevance to managing ecosystems on military installa-

[1] Botkin, et al., 1997.

tions, its effectiveness at transferring its results, and its management structure.

An effective research and development program requires a clear strategic plan, the highest quality investigators and projects, and effective management. All three components are critical for success. This chapter describes a new management structure and processes that will be supportive of these elements. A separate white paper lays out the current goals and strategy for SEMP.

Starting with the October 2003 SERDP SAB review of SEMP, the SERDP office has conducted a number of activities to identify shortfalls in the program and opportunities for improvement. Figure 2-1 identifies the key steps conducted in this review. The proposed management changes are directly in response to these reviews and workshops.

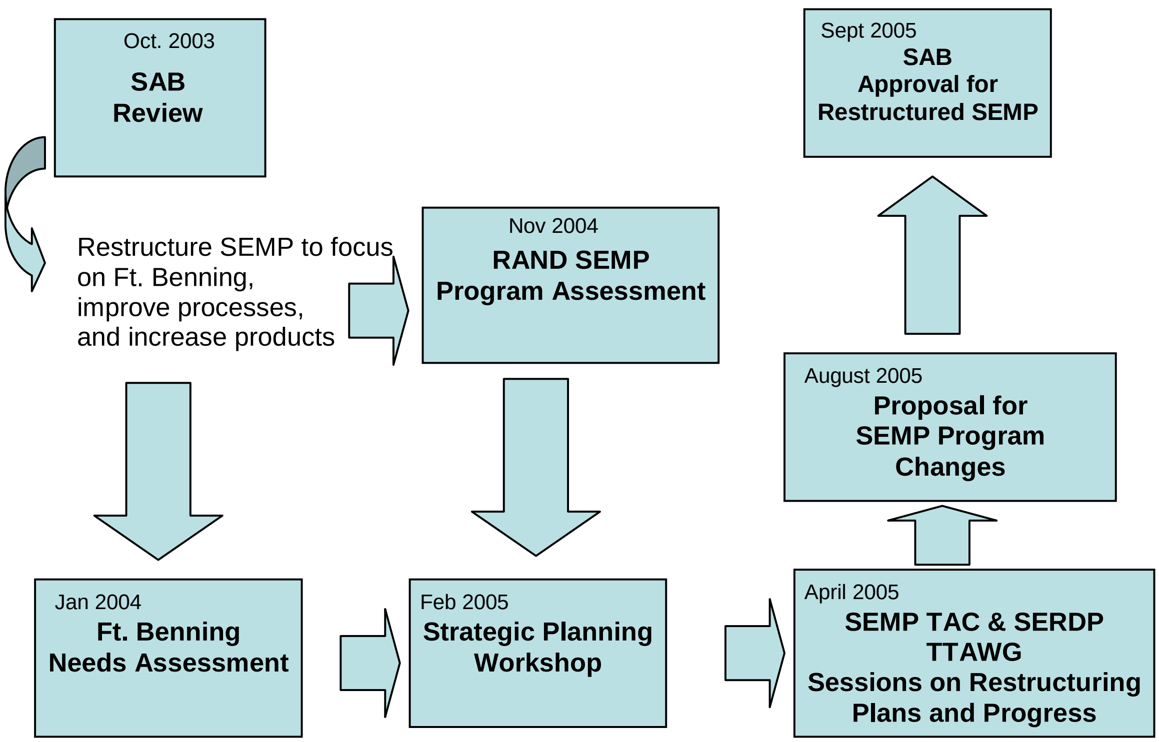

Figure 2-1. Schematic Illustrating SEMP Reviews and Actions for Restructuring.

2.0 Fort Benning – Military Context

The mission of SEMP is to conduct high-quality applied ecosystem research in support of ecosystem management challenges at military installations. The military context of SEMP presents unique challenges. Conducting ecosystem research requires long-term field studies. Fort Benning, GA, is an active military installation conducting ongoing and changing military missions. It is not a static site with unrestricted access to all land areas. Mission activities often preclude access for scientific study.

Fort Benning is located on the fall line of the coastal plains and piedmont regions, with some property in both regions, and shares many of the same ecosystem properties and problems present in other military and federally-managed lands of the region. The ecosystem problems relate to thin productive soils, erosion and the presence of numerous endangered and threatened species. Also, the increases in mission intensity at Fort Benning are manifest in recent construction of a new range and expectations for increased personnel, training, and merger of missions created by BRAC actions. Concomitantly, the Columbus, GA, area is experiencing rapid economic development, in part to support Fort Benning activities. There are other Defense bases along this fall line region, which is the transition zone between the Piedmont and the Coastal Plain (Figure 2-2). Fort Benning's land management concerns are typical of many of these military installations in the southeast of the United States.

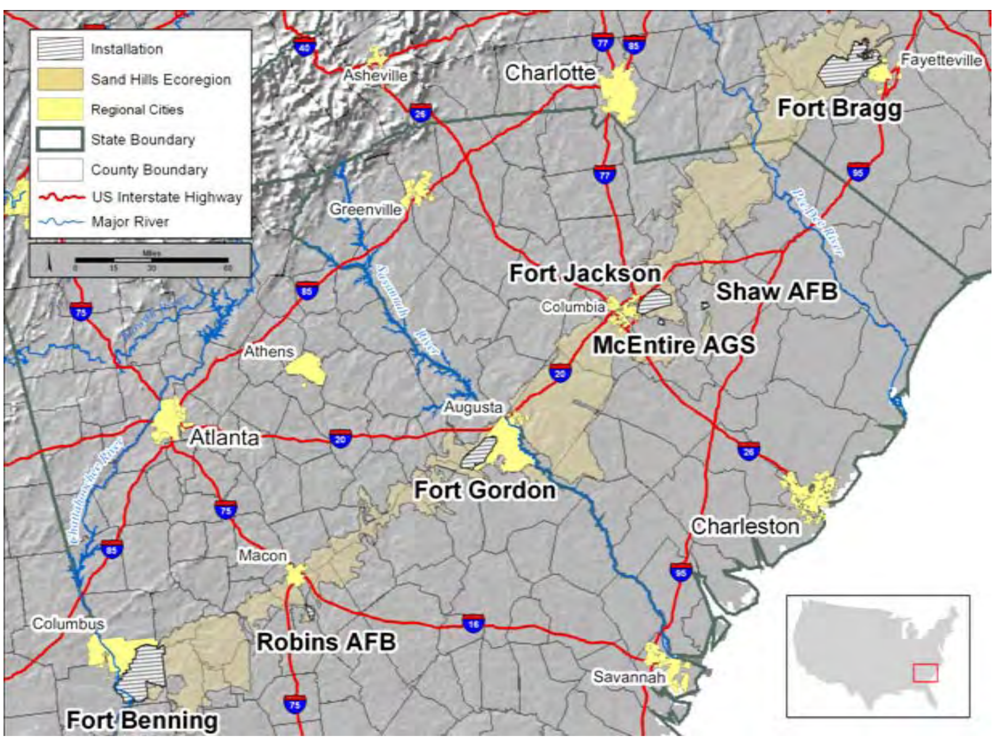

Figure 2-2. Map of the southeastern United States showing the locations of military installations relative to the fall line-sandhills ecoregion.

3.0 RAND Recommendations

The SERDP Office commissioned the RAND Corporation to conduct an independent review of SEMP. The scope and recommendations of this review addressed scientific content issues as well as the management and administrative elements.[2] Table 2-1 briefly summarizes their recommendations.

Table 2-1. Summary of RAND Review Recommendations.

Review	Date	Findings & Recommendations

RAND	Nov 2004	▪ Conduct Strategic Planning
		  ▪ Conduct an analysis and have a visioning workshop to develop a SEMP strategic plan
		  ▪ Create a balanced research portfolio for SEMP
		  ▪ Consider some fundamental changes in SEMP approach
		▪ SEMP More Relevant to Installation Management Needs
		  ▪ Incorporate installation management needs into SEMP research activities
		  ▪ Improve coordination and communication with Fort Benning
		  ▪ Hire part time installation technical liaison at Fort Benning
		  ▪ Improve base knowledge among SEMP participants
		  ▪ Have data repository staff located at Fort Benning
		  ▪ Conduct more in-depth planning for technology transfer
		▪ Develop Comprehensive Ecosystem Science Foundation
		  ▪ Develop a project portfolio that looks more comprehensively at ecosystem processes, and ecological and management priorities
		  ▪ For current slate of projects, be sure to document applicability and limitations of research
		  ▪ For future research projects, consider ways to address current deficiencies; for example
		  ▪ Address species of concern or unique ecological areas in indicator work
		  ▪ Develop ecological process models
		  ▪ Address spatial and temporal scales
		  ▪ Focus more on adaptive management
		▪ Improve QA/QC
		  ▪ Develop appropriate performance metrics and consequences if not met
		  ▪ Improve proposal review processes
		  ▪ Improve project review
		  ▪ Bring in external experts to help with evaluations
		▪ Revise the SON Process and Other Ways that SEMP Funds Activities
		  ▪ Planning and analysis needed to revise the SON development process
		  ▪ Conduct more in-depth analysis and review before funding non-competitive activities

[2] Lachman, Beth, Noreen Clancy, and Gary Cecchine, Assessment of the SERDP Ecosystem Management Project (SEMP), RAND Arroyo Center, November 2004.

Review	Date	Findings & Recommendations
		▪ Improve Communication and Coordination Planning, Methods, and Products ▪ Hire a communications analyst ▪ Develop a communications plan ▪ Require projects to produce and update a comprehensive annual report ▪ Address coordination issues ▪ Improve SEMP Administration ▪ Address staffing needs ▪ Provide more staff time for SEMP administration ▪ Address administrative procedures that have potential conflict of interest ▪ Improve the Functioning of the TAC ▪ Ensure appropriate TAC expertise ▪ Strengthen orientation for new TAC members ▪ Improve the TAC's ability to provide oversight

The management structure and processes described below directly address the management-relevant findings and are supportive of plans to address the strategic planning and scientific shortfalls identified.

4.0 SEMP Management Structure

Management process and structure are not separable. For clarity we first outline the structure and in the following section show how this structure will be used to manage the research program. Figure 2-3 illustrates the new SEMP management structure.

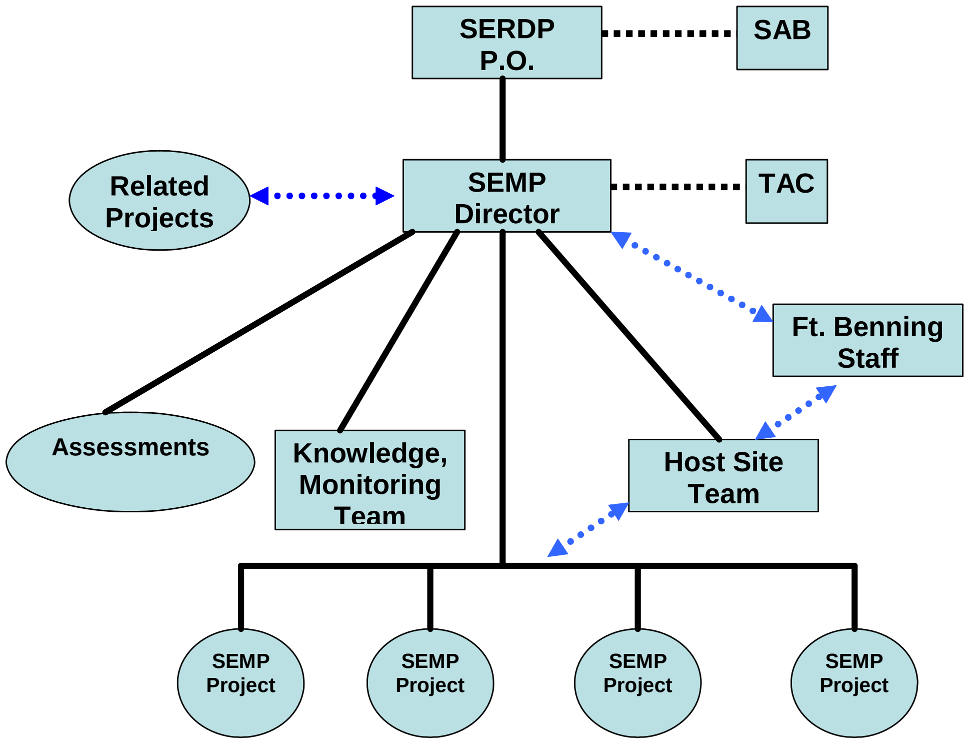

Figure 2-3. SEMP Management Structure.
Solid black lines represent direct management and reporting, dashed black lines represent advisory role, and the dashed arrowhead lines represent coordination activity.

The organizational structure depicted in Figure 2-3 differentiates between direct management and reporting chain, advisory roles, and coordination activities. All three types of activities are critical for the success of SEMP but it is important to clearly differentiate these roles. Also this figure graphically differentiates standing or infrastructure functions (rectangles) from research projects or assessments (ovals) that are expected to have finite lifetimes within the operational life of SEMP.

Roles and Responsibilities

Many of the proposed changes in the SEMP management structure imply and require shifts in the roles and responsibilities of specific positions as well as designated committees or groups. Detailed below are the specific roles and responsibilities in SEMP of each group identified above.

Oversight

As in all SERDP investments, the SERDP program office remains ultimately responsible for the execution and quality of work.

SERDP Program Office

The SERDP Program Office consists of the Sustainable Infrastructure Program Manager, the SERDP Technical and Executive Director, and the Sustainable Infrastructure Technical Thrust Area Working Group (TTAWG) (now referred to as the SERDP Technical Committee - STC). SEMP projects, research infrastructure and solicitations will be managed through the normal mode of SERDP oversight. All efforts will be reviewed annually at the project level by the STC and all solicitation will be part of the annual SERDP Statement of Need (SON) solicitation. The standard methodology for tracking financial and technical execution will be used for all SEMP projects as well as research infrastructure funding and activities.

Scientific Advisory Board

The SAB will see all SEMP projects awarded via SONs in the usual manner consistent with SERDP processes. The SEMP Director, when requested by the SERDP Executive Director, will brief the SAB on the SEMP Program as a whole, the research infrastructure, and specific science/technology assessments.

Research Infrastructure

The research infrastructure is required to identify and plan for future investments, execute and manage ongoing projects, and transfer the results to natural resource managers. Annual budgets will be fully justified and included in the annual plan submitted for approval by the SERDP Program Manager and SERDP Executive Director. Periodic reviews of the nature and extent of the costs for these functions will be conducted.

SEMP Director

The SEMP Director will assume responsibility for the strategic direction and management of the SEMP program. Among the Director's responsibilities are to: 1) foster a team-oriented approach to SEMP research projects and Fort Benning interests; 2) provide technical oversight to all SEMP projects; 3) directly manage the SEMP research infrastructure; 4) work with the TAC in developing SONs; 5) measure progress toward meeting program goals and outcomes; 6) work with the TAC and Fort Benning staff to develop and execute science/technology assessments and transition efforts; 7) develop associations with and liaison to all non-SEMP SERDP, ESTCP, legacy, Army EQT, and other projects at Fort Benning and in other installations along the fall line relevant to the SEMP goals; 8) represent the SEMP program among relevant research and operational communities with a view toward influencing their science content, increasing collaboration with the SEMP program, and enabling technology transfer and application; and 9) provide plans, budgets, and recommendations to SERDP executive and management staff relative to research direction, transition-ready technologies, and policy-relevant findings.

SEMP TAC

The SEMP Technical Advisory Committee (TAC) is a diverse group of experts representing the disciplines and experience necessary to provide ongoing advice on the scientific strategy and direction of SEMP and SEMP projects. The TAC is transitioning from a largely peer review function and quasi management to a peer input function, akin to a Board of Directors function. The members will participate as appropriate in the topic selection and completion of scientific assessments directed toward providing operational guidance and generating research needs and hypotheses and will develop ongoing peer collaborative oversight and advisory roles with individual projects as resources and expertise permit.

SEMP Administrative Staff

The SEMP Administrative Staff will provide administrative support to the SEMP Director as required and appropriate; this support will be provided by the ERDC-CERL support staff. The budget for this function is expected to be modest.

Knowledge Management Team

This team will provide, populate, and enhance the GIS and web-based systems at Fort Benning (and accessible by others) that include the SEMP baseline monitoring data, project data, reports, models, and decision-support tools.

Monitoring Team

This team will manage baseline ecosystem monitoring in support of SEMP. The team will also provide directions as to the changing ecosystem monitoring needs by both the research community and the installation environmental personnel in order to have an effective monitoring program.

Host Site Team

The onsite SEMP staff includes the Host Site Coordinator and the Technology Infusion Expert. The Host Site Coordinator serves as the communication link among all interested parties funded by SEMP at Fort Benning. The position is critical to allow ecosystem research to be conducted at an operational military base. The Technical Infusion Coordinator focuses on identifying and integrating SEMP results into Fort Benning operations. This staff will provide day-to-day SEMP and SEMP Projects interaction with Fort Benning staff and provide technical and administrative support for the technology assessment and transition functions. Both will assist Fort Benning staff to design and implement approved adaptive management projects suggested by the science assessment activities.

Technology Assessment and Transition

A new element of SEMP will be a formal set of assessments to identify opportunities to transition SEMP results and define areas of future ecosystem research that support ecosystem management and the SEMP strategy. These assessments will be planned, topic-focused, and involve both the researchers and resource managers. They are the responsibility of the SEMP Director. They will be proposed on an annual basis and justified as part of the SEMP budget.

Research Projects

The core of SEMP will remain the principal investigator-led research projects. Two classes of projects exist: 1) those formally managed in SEMP and 2) related research efforts. The SEMP projects will be selected on a competitive basis as are other SERDP projects. SEMP research projects must address ecosystem science and technology issues that are relevant to ecosystem management at military installations. They must be executed predominately at Fort Benning and be consistent with the SEMP strategy and designed to meet SEMP goals and objectives.

SEMP Projects

SEMP Projects are SERDP projects funded from SEMP-generated SONs and awarded as part of the SERDP-STC process. In addition, SERDP projects maybe awarded, originating from other SERDP SONs that have proposed interaction with the SEMP program or Fort Benning. The inclusion of such projects is subject to the approval of and the coordination with the SERDP Program Office.

Related Projects

These are non-SERDP projects (e.g., ESTCP, Legacy, Army EQT, Fort Benning, etc.) that have relevant interactions with Fort Benning and address the SEMP goals.

5.0 SEMP Management Process

The overall management of SEMP research can be divided into four phases as illustrated in Figure 2-4.

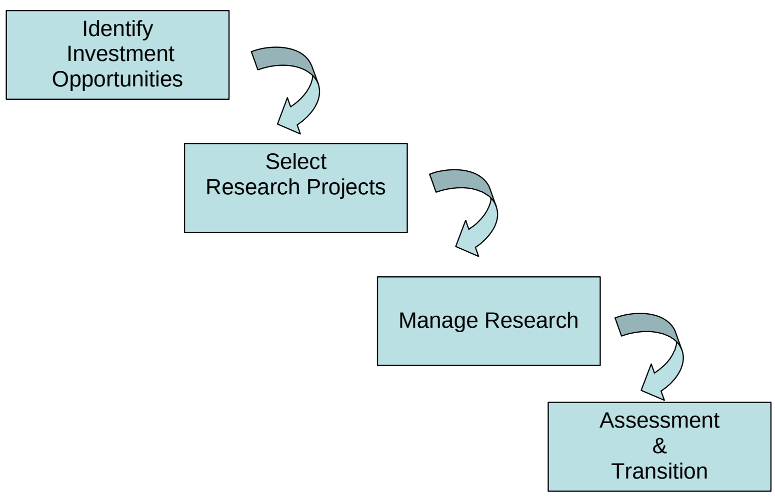

Figure 2-4. SEMP research management phases.

Breakdowns in any one of these areas will significantly limit the value of SEMP. In addition, this is really a circular process, where science and technology assessments lead to transition of new tools to natural resource managers and identification of areas that require further research.

The RAND review and others have identified opportunities for SEMP to improve in all these phases. As pointed out by the RAND review, none of this can be effective in the absence of clear goals and a strategy. Those topics are discussed in a separate white paper. Here we outline the mechanistic aspects of managing SEMP under the structure discussed in section 4.0, above. The challenge remains to link the science-based nature of the SEMP with the management needs of Fort Benning and other military installations. Clearly, in order for SEMP to contribute to the state of the art in ecosystem management while also participating in Fort Benning natural resource management operations, it is necessary to strengthen the interactive role of SEMP projects, other SERDP projects, related DoD projects, and Fort Benning staff.

Identify Investment Opportunities

The core of SEMP remains investigator-led research. A challenge for the SEMP program is the formulation of specific hypotheses that rise to the level of SERDP SONs and that also deal specifically with Fort Benning issues. The SEMP Director is responsible for the development of potential SONs. Given the "baseline" orientation of the program in its first phase and the general goals identified in the 1997 workshop to develop a monitoring program and examine indicators and thresholds, this was not judged to be a major problem. During the next phase of SEMP a more structured and analysis-rich approach is desired. The reviews noted this as well. Accordingly, it is instructive to look at the science assessments as the best means to generate hypotheses that can be used to propose SONs to the SERDP program. A science assessment will necessarily include a thoughtful analysis of both available information from SEMP and will have also looked carefully at the literature and state of the practice. In the ecosystem management paradigm, this step will inform both "experimental management" at Fort Benning and serve the SON development process. The mechanism for developing these will be discussed below.

These draft SONS will be provided to the SERDP Sustainable Infrastructure STC to be considered along with other SONs for that year. The SERDP Program Office will issue these SEMP SONs with the annual solicitation each November.

Select Research Projects

The selection of SEMP projects in response to a SEMP SON will follow the standard SERDP process. All proposals will undergo external peer review. The top tier of proposals, based on the peer review, will be provided to the SERDP Sustainable Infrastructure STC for consideration. The SEMP Director will serve as a member of the STC during the review of these proposals. The STC's recommendation along with any additional recommendations from the SEMP Director will be provided to the SERDP Executive director through the normal SERDP evaluation process. All proposals selected for funding consideration by the Executive Director will be reviewed by the SERDP SAB.

Manage Research Projects

The SEMP Director will have direct management supervision over SEMP projects. He will serve as Contracting Officer Representative. All projects will report their financial and technical execution through the SERDP web-based management system. These reporting requirements include monthly financial reports, quarterly technical status reports, and annual technical reports. SEMP projects will be reviewed annually during the Sustainable Infrastructure In-Progress Review (IPR) at the SERDP office. The SEMP director will participate in these reviews.

SEMP - PIs will also be expected to meet at least annually in an “all investigators” forum for the purpose of exchanging “progress and problems.” This forum is not the same as the SERDP-required IPRs. The IPRs cover the science content but are also directed to the “relevance stakeholders,” the budget-relevant progress milestones interests, and the SERDP staff. The IPRs do not provide the opportunity or the expectation for establishing meaningful PI collaboration and integration. The SEMP Director is responsible for organizing and managing this annual meeting. It will serve as an opportunity to coordinate SEMP projects and other relevant work being conducted at Fort Benning. The SEMP TAC will participate in this meeting and hold their annual “board of directors” meeting at its conclusion.

Assessments and Transition

Scientific and Adaptive or Mitigation Options Assessments is the heart of the interaction between SEMP researchers (and other scientists or invited experts) and Fort Benning staff. The assessments must be planned, topic-focused, and involve both the researchers and resource managers. Note that new hypotheses as well as management or policy recommendations flow from the assessment step. This step is the heart of the ecosystem management paradigm when combined with the monitoring feedbacks and stakeholder interactions.

The use of the assessment step is also key to the technology infusion and transition from research to operational status as well as identification of potential new SONs. Consider Figure 2-5 as an elaboration on this step.

The approach briefly described here is also implementation of many of the RAND review recommendations and results in approaches that also generally conform to the principles and elements of ecosystem management.[3] The approach illustrates the Fort Benning focus while retaining the research foci with enhancement from the scientific assessment step providing, among other thrusts, new hypotheses and research needs. This step is also proposed as the key step in generating better informed and more relevant SONs for consideration by the STC and SERDP Office. Science assessments can vary from comprehensive and resource intensive efforts for major program accomplishments, somewhat akin to the indicator integration project, to very specific and targeted efforts. Assessments as described here will require resources and will be budgeted and justified on an annual basis.

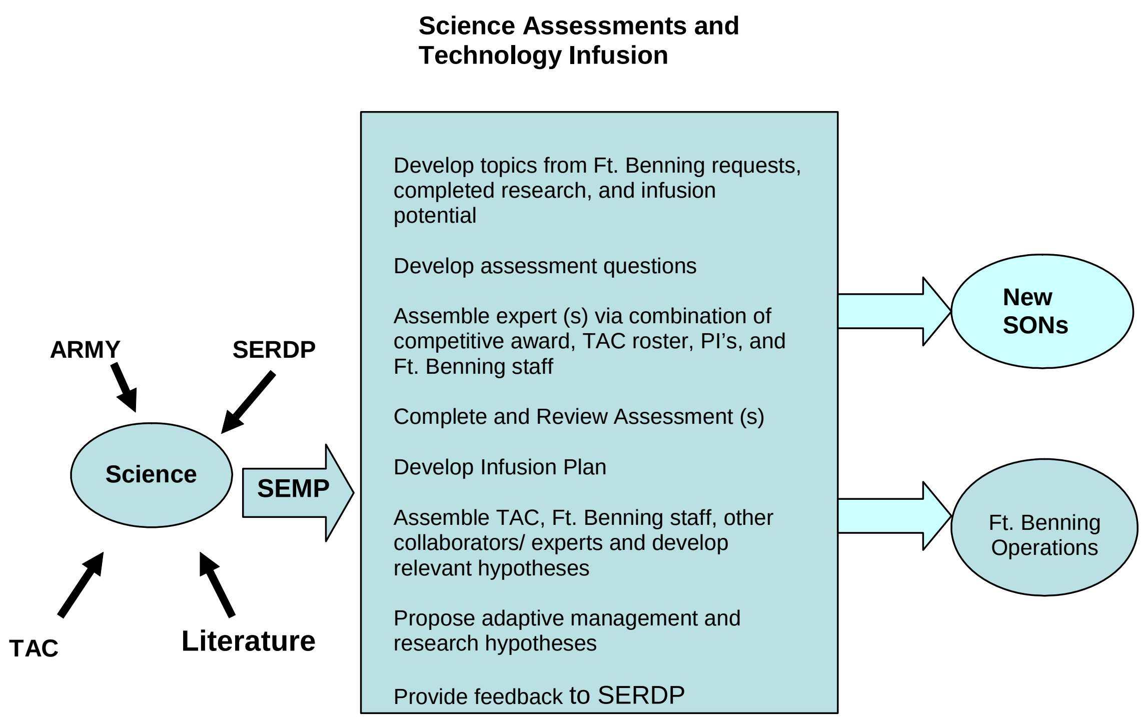

Figure 2-5. Proposed Approach to Science Assessments and Technology Infusion Planning.

[3] Christensen, Norman L., Ann M. Bartuska, James H. Brown, Stephen Carpenter, Carla D'Antonio, Robert Francis, Jerry F. Franklin, James A. MacMahon, Reed F. Noss, David J. Parsons, Charles H. Peterson, Monica G. Turner, and Robert G. Woodmansee, The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management, Ecological Society of America, 1995.

6.0 Conclusion and Path Forward

SEMP was initiated to combine the ongoing natural resource management activities at one or more military bases with an interactive research program designed to advance the scientific basis for the concept of ecosystem management. The program has been critically reviewed and in response to those reviews, a number of major changes are already underway. When the reviews were initiated, many of the projects were incomplete and the number and types of products were limited; over the past 2 years, the first round of five projects have been completed, the publications have been growing in number and substantive content, and a concentrated effort has been made to integrate the results from many of the projects. That said, SEMP can be viewed as having finished a first phase and now has a platform from which to launch the second phase.

This transition to the next phase for SEMP has been underway throughout 2004 and 2005. New databases and interfaces have been created to improve the value of and access to SEMP repositories. Monitoring efforts have been transitioning from ERDC to Fort Benning, with several Fort Benning staff members learning specific monitoring tasks and integrating these into their daily decision-making and reporting. New SEMP staff are already in place at Fort Benning, and the base has mobilized their workforce to be more strongly engaged in SEMP.

The major transitions not yet implemented are formalizations of the Technology Assessment and Technology Infusion processes. They are designed to bridge the gap between science knowledge and tools and installation operations, to ensure that research developed under SEMP helps Fort Benning (and other bases) use the best available knowledge and capabilities to address ecosystem management challenges, and that future SEMP research targets the key ecosystem science issues relevant for ecosystem management at military installations.

3 SEMP Meetings and Workshops

This chapter contains a chronological listing of the participation in professional conferences and formal project meetings and workshops with which SEMP researchers, managers, and Advisory Committee members were involved between October 1, 2004 and December 31, 2005.

American Society of Agronomy Meeting

October 31-November 4, 2004, Seattle Washington

There were several posters and presentations given at this meeting. John Dilustro with Dr. Beverly Collins and Lisa Duncan gave a Powerpoint presentation titled "Soil Nitrogen Availability in Mixed Forests of Varying Management, Military Use and Soil Texture," describing their work in project CS-1114E. Maria L. Silveira, K. R. Reddy, and N. B. Comerford presented another slideshow titled "Initial Litter Decomposition and Dissolved Organic Carbon Release in a Forest Ecosystem," detailing part of what their CS-1114A research project has done. Lupe G. Cavalcanti presented "Effects of sediment deposition on aboveground net primary productivity, vegetation composition, structure, and fine root dynamics in riparian forests" from findings at Auburn University. Dr. Hal Balbach and Tony Krzysik presented a poster. Their published abstracts follow.

Soil Nitrogen Availability in Mixed Forests of Varying Management, Military Use and Soil Texture

J. Dilustro - Univ. of Georgia SREL, B. Collins - Univ. of Georgia SREL, L. Duncan - Univ. of Georgia SREL

Soil nitrogen cycling is influenced by soil texture, nitrogen inputs, vegetation, and land use. We analyzed soil nitrogen mineralization, nitrification, and leaching in mixed pine hardwood forests as part of a study examining land use and soil texture effects on vegetation and nitrogen dynamics at Fort Benning, Georgia. These forests are managed by prescribed fire (3-year rotation), and burns were conducted on all sites prior to our research. The 32 forest stands sampled range from sandy to clayey soil texture and lighter (infantry) to heavier (mechanized) military training intensity. Pooled soil organic layers were collected from all sites in 2001, 2002, and 2003 and laboratory incubations were used to measure soil mineralization and nitrification during the growing seasons. Initial laboratory results indicate greater initial extractable mineral soil nitrogen in clayey sites with lighter land use intensity. After 84 days, heavier use areas with sandy soils had the greatest nitrate production and overall mineral nitrogen pool. Organic layer dry mass (1166 g/m^2) and nitrogen pool (8.7 g N/m^2) were greatest in clayey sites with lighter military training. Evaluating soil nitrogen transformations can help guide management practices to enhance productivity in these southeastern mixed pine hardwood forests.

Initial Litter Decomposition and Dissolved Organic Carbon Release in a Forest Ecosystem

M.L. Silveira - University of Florida, K.R. Reddy - University of Florida, N.B. Comerford - University of Florida

Litter is an important source of easily mineralizable C and N for microbial metabolism in forests; however, its decomposition is dependent upon a variety of factors, including litter chemical composition and soil characteristics. This experiment was designed to investigate the decomposition of litters incubated with soil, and to examine the C and N transformations during the mineralization process. Soil and litter samples were collected from Fort Benning military reservation in west-central Georgia. Soil was placed in a funnel vacuum filter system, and freshly fallen leaf litters were added to the soil surface. The containers were kept in a dark cabinet, and CO2 production was trapped in NaOH solution. Once a week, the containers were opened and leached with DDI water. The majority of C loss was due to CO_2 production, and varied noticeably among the treatments. The largest dissolved organic C and N pulses were observed in the initial weeks, and were directly related to the litter species. In general, organic N was the major source of N in leachates; however, inorganic N accounted for a significant fraction in wetland soils. Total C and N, followed by C:N ratio were significantly correlated to C loss. The changes in chemical composition of litters after incubation revealed a preferential loss of more labile components in response to the decomposition process.

Site Comparison Index: Can We Create a Meaningful Index Value to Rank Site Condition?

H.E. Balbach - US Army ERDC-CERL, Champaign, IL and A.J. Krzysik - Prescott College, Prescott, AZ

The SERDP Ecosystem Management Project (SEMP), a Defense research program hosted by Fort Benning, GA, is a set of related projects examining ecosystem management. Soils, vegetation, and military use aspects are part of a systematic study to assist military installation land managers to better weigh demands for sustainable mission use and proactive stewardship. Adaptive management tools will be developed based on relating SEMP research findings to management concerns. The different research teams, from many universities and U.S. Government laboratories, planned their studies and chose their study sites with reference only to that team's goals. Each team ranked their respective sites on a subjective Low, Medium, High disturbance scale. Later, when teams were presenting their results to the same review panel, it became clear that there was no consistent way to relate, for example, the different definitions of "medium" across the teams. To create an objective site comparison index (SCI), a combination of metrics: soil A-horizon depth, soil compaction, ground cover, canopy cover, basal area, remote sensed NDVI, and soil carbon and nitrogen, were evaluated in 2003 across a broad disturbance gradient and forest community types at Fort Benning. The results generally support the application and utility of a SCI, at least in comparable environments.

SERDP Symposium

November 30 - December 2, 2004, Washington, DC
The following posters were presented at this symposium:

- Simulating Effects of Roads at Different Scales

Dr. Viginia Dale
Co-Performers: Matthew Aldridge; Latha Baskaran; Dr. Michael Berry; Dr. Michael Chang; Dr. Daniel Druckenbrod; Dr. Rebecca Efroymson; Charles Garten; Dr. Robert Washington-Allen.

- Riparian Ecosystems at Fort Benning, Georgia: Impact Assessment and Restoration

Dr. Patrick Mulholland
Co-Performers: Dr. Jack Feminella; Dr. Graeme Lockaby; Dr. Jeffrey Houser; Dr. Brian Roberts; Gaudalupe Cavalcanti; Rachel Jolley; Stephanie Miller; Richard Mitchell; Gary Hollon.

- Development of Ecological Indictor Guilds for Land Management: Identifying Ecological Indicator Guilds and a Plot Level Site Comparison Index for Southeastern Sandhills.

Dr. Anthony J. Krzysik
Co-Performers: David A. Kovacic; John H. Graham; Michael P. Wallace; Jeffrey J. Duda; John C. Zak; Harold E. Balbach; D. Carl Freeman; John M Emlen.

- Land Management and Military Use Effects on Soil Nitrogen Cycling in Upland Forests at Fort Benning, Georgia.

Dr. Beverly Collins

Co-Performers: Dr. John Dilustro; Lisa Duncan; Sara Drake; Dr. Rebecca Sharitz.

- Effects of Tracked-Vehicle Disturbance on Longleaf-Pine Understory Vegetation Through Two Growing Seasons

Dr. Daniel Druckenbrod

Co-Performer: Dr. Virginia H. Dale

SEMP Phase II Strategic Planning Workshop

February 1-2, 2005, Sheraton Hotel, Columbus GA

Background: The Strategic Environmental Research and Development Program (http://www.serdp.org) is a congressionally authorized activity, under the office of the Secretary of Defense, that provides research strategies and projects that address environmental challenges of the Department of Defense, in collaboration with the Department of Energy and the Environmental Protection Agency. The Defense services regularly define their overall research challenges, and, during the 1990s, several services identified challenges relating to managing military lands according to ecosystem management principles. These specific research challenges reflected guidance, issued by the Office of the Secretary of Defense and echoed by each service, for military installations to proactively manage their lands with adaptive ecosystem management approaches that incorporated state of the art scientific knowledge and technologies.

To further define this broad requirement for "ecosystem management approaches," SERDP sponsored a Landscape Scale Ecosystem Management Workshop in June 1997. Dr. Daniel Botkin chaired the committee that planned and led this workshop and produced a workshop report.[1] Following the workshop, the SERDP Program Office, in consultation with the SERDP Scientific Advisory Board, decided to initiate a long-term ecosystem research project. This project, entitled the SERDP Ecosystem Management Project (http://semp.cecer.army.mil) was initiated at Fort Benning, Georgia, in 1999, with both research and long-term monitoring activities.

[1] Botkin, B.D., P. Megonigal, and N. Sampson, Summary Report: Management-Scale Ecosystem Research Workshop, unpublished report to SERDP Program Office, 1997.

The project has now completed 5 years of effort (1999-2004). During 2004, the RAND Corporation undertook an extensive study of SEMP approaches, accomplishments, procedures, and problems. Dr. Beth Lachman of RAND delivered a draft summary of this report to the SERDP Scientific Advisory Board in Sept 2004, then provided a final report in November. In this report, Dr. Lachman recommended that SEMP undertake a new strategic planning process to shape the future of SEMP.

Workshop Purpose: The SEMP Phase II Strategic Planning Workshop was intended to help shape both an overall strategy and an action plan for the next 5 years (and beyond) for SEMP. From this workshop, the SERDP Program Office, SEMP managers, and the SEMP host site participates (from Fort Benning and other installations in the region) hoped to identify key management challenges still requiring ecosystem management research solutions, improved approaches to transition knowledge, protocols and tools from research to operations, and improved approaches to building, managing, sharing and growing long-term ecosystem monitoring and research data. In the workshop Recommendations from the 2004 RAND Assessment of SEMP helped provide an important framework to build upon during the workshop.

Workshop Participants: The SERDP Program Office invited about 30 people to participate in this workshop. Participants included:

- SERDP Program Office, including the SERDP Executive Director, the Conservation Program Manager, and various supporting staff. SERDP Program Office supporting staff from HydroGeoLogic facilitated and supported this workshop.
- Members of the SEMP Technical Advisory Committee (TAC). The SEMP TAC consists of experts with various ecosystem research and management expertise that provide scientific oversight and advisory input to SEMP management and the SERDP Program Office.
- Staff from Fort Benning Environmental and Training organizations.
- Selected representatives from Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. ERDC staff have managed SEMP from 1999-2004.
- Members of the former SERDP Conservation Technology Thrust Area Working Group (TTAWG) that advised SERDP on Conservation research strategies and needs, evaluates new proposals and project progress.

- Staff from other installations in the region.
- Experts beyond the SEMP TAC with relevant expertise in ecosystem management research state-of-the-art efforts.

Scope for the Workshop: The focus was primarily on the next 5-year phase of SEMP (FY05-09), but it also considered long-term concerns that might require work beyond FY09. The host site is still Fort Benning – but recommendations from the workshop also addressed extensions of SEMP activities and outcomes to installations along the Sand Hills Fall Line and to other locations across the Southeastern United States.

Product from the Workshop: This workshop was a highlight in a process leading towards a new strategy for SEMP. This strategy must provide valuable research outcomes that also yield direct benefit to the host installation(s). The product from this workshop was primarily recommendations for key research themes, approaches and capabilities. These recommendations were incorporated into an overall strategic plan which was briefed to the SERDP Scientific Advisory Board in June 2005.

2nd Partners Along the Fall Line Workshop

March 8-10, 2005, Conference Center for the Savannah River Ecology Laboratory (SREL).

Sponsors: This workshop was sponsored by the Strategic Environmental Research and Development Program (SERDP) and coordinated by the U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC).

Planning Committee: SERDP, ERDC, SREL, Fort Benning, Army Southeast Regional Coordination Office, U.S. Fish and Wildlife Service, U.S. Forest Service, The Nature Conservancy, and others served as members of the workshop planning committee. Committee members are posted on the workshop website and listed in the workshop program published by SREL. Website: http://www.uga.edu/srel/fallline05/.

Attendees: Over 50 persons from military bases, State Departments of Natural Resources, U.S. Forest Service, U.S. Fish and Wildlife Service, The Nature Conservancy, The Conservation Fund, Savannah River Site, Forest Products Inventory and others. Attendance was highest during the first morning, Tuesday, March 8, when the meeting included about 15 participants associated with the Southeast Natural Resources Leaders Group (SENRLG), a regional association of federal agencies that attempts to coordinate their efforts across the Southeast. This group then held a meeting in nearby Augusta during Tuesday afternoon.

Presentations: There were several excellent presentations throughout the workshop, including the welcoming address from Dr. Rebecca Sharitz of the Savannah River Ecology Lab, remarks by Patricia Hook of the National Park Service and Chair of the SENRLG, and the keynote talk by Dr. Sam Pearsall of The Nature Conservancy. Dr. Pearsall focused on the necessary elements of successful partnerships. Generally, presentations were given by speakers and panels during the morning, then in the afternoons, participants formed workgroups to identify and pursue specific issues and concerns.

Posters: In addition to the workshop presentations, there were several posters provided by teams that have research projects relevant to Fall Line land managers. These included regional research projects sponsored by SERDP, including the SERDP Ecosystem Management Project (SEMP) effort at Fort Benning; the Oak Ridge National Lab regional simulation of the Fort Benning area; the Forest Service replanting study for longleaf pine at Camp Lejeune; a Fall Line research effort by SREL that has sites at SRS, Fort Gordon, and Fort Benning; and gopher tortoise research efforts sponsored by ERDC.

Workshop Outcomes: One of the primary purposes of this workshop was to facilitate partnership plans related to land and resource management issues along the Sandhills Fall Line region. The workshop participants were asked to consider relevant topics and partnering approach issues. During the discussion, two key topics emerged:

- Preservation efforts related to species in the region that are threatened but not yet federally listed. The gopher tortoise was introduced as an example of such a species.
- Fire as a tool in managing sustainable habitat in regional forests.

Preservation Efforts for Sensitive Species: Participants not only identified this as a key concern, but were able to suggest some very specific steps. Participants agreed to pursue the development of a Conservation Agreement to proactively conserve and restore populations of the gopher tortoise and associated species, first along the Fall Line region and then throughout the eastern range of the species. Gopher tortoise is already federally listed as endangered in its western range, but has not been listed in its eastern range, which includes Georgia and southern portions of South Carolina. Several parties expressed a willingness to participate in the development of this conservation agreement, including the Georgia and South Carolina departments of natural resources, the Fish and Wildlife Service, Fort Benning, Fort Gordon, Savannah River Site, The Nature Conservancy, The Conservation Fund, and several supporting organizations (SERDP, ERDC, and the Army's Southeast Regional Coordination Office). The Georgia Department of Natural Resources agreed to initiate planning efforts towards the development of this agreement. Participating organizations will be engaged in efforts to secure sufficient habitat across the region to ensure the improved survival of this species and its associates. Gopher tortoise is a keystone species, and several other species, some rare or endangered, depend on the gopher tortoise burrows. Participants also identified some research needs related to the gopher tortoise–such as the size of a viable population, and the linkages between geographically separate populations in a region. These needs will be considered by Army and SERDP research programs.

Georgia and South Carolina DNR are currently developing state conservation plans, which will be presented and reviewed in autumn 2005. The goal is to have a conservation agreement, staffed among the participating organizations, before these autumn reviews, because the DNR plans could help support this agreement by identifying target areas and resources for habitat conservation actions. Geographically, the agreement would focus first on the Fall Line, then attempt to bring in other partners who have interests across the eastern range of the gopher tortoise.

The effort to develop a conservation agreement could provide considerable value to Defense installations. Gopher tortoises occur on multiple military bases in the Southeast, and, if listed, protection of their habitat could represent a significant constraint to the training mission at these bases. In addition, Fort Benning, which is home to many tortoises, will be increasing the training levels on installation lands. With new units assigned to Benning, concerns about increased training levels impact on these tortoises may emerge from various stakeholder groups.

A proactive effort to plan a landscape level approach for species preservation, which includes both preservation and restoration projects, will help provide the commanders on the military bases that host these tortoises with “room to negotiate” with Fish and Wildlife service regarding any potential impacts of training to gopher tortoise.

The agreement will be modeled after the Cooperative Agreement developed for the Florida Greenway. This agreement, which has helped structure the preservation of large land areas along the Florida panhandle, is a relatively simple document providing a statement of goals and a listing of the stakeholders and each of their interests and responsibilities. Detailed plans and specific responsibilities for actions would be captured in work plans that are associated with the target conservation agreement and updated regularly by the involved parties.

This agreement can build upon excellent research efforts and studies that have already been focused on the gopher tortoise, including one sponsored by SERDP and conducted at Forts Benning and Gordon, and the Savannah River Site by SREL. In addition to this project, there are habitat-related mapping efforts from the Environmental Protection Agency’s Southeastern Ecological Framework, the Georgia and South Carolina DNR’s conservation plan maps, and some habitat mapping efforts by non-government agencies in the region (including The Nature Conservancy and The Conservation Fund). A current Legacy Resource Management Project, scheduled to start this year, could also be focused on supporting this emerging partnership by reviewing and comparing these multiple mapping efforts, and identifying prime regional habitat for the gopher tortoise.

Fire Management Along the Fall Line: A second topic of general concern was the effectiveness of controlled burning for achieving forest management objectives at both the stand and the landscape scales. Concerns were voiced regarding numerous issues, such as:

- regional contributions of smoke and particulates from burning;
- loss of trees, including longleaf pines, during or after burning;
- burning in areas with high fuel loads;
- the manpower and cost requirements of burning programs over large acreages; and
- the overall regional impacts of stand burning.

Two key actions were recommended from these discussions. First, participants thought that regular discussions among the practitioners and managers of controlled burning programs could provide a needed forum for sharing best practices. Second, participants discussed the possibility of structuring an “adaptive management” research effort that gathers data from ongoing management efforts and then brings these data into an analysis framework to pursue several of the management questions. These data could also be presented at the discussion forums to facilitate structured learning by all participating practitioners. This would engage the community in a coordinated effort to “learn” from ongoing management.

Fort Benning agreed to host the first of the “Fire Along the Fall Line” forums, and the SERDP SEMP effort will develop plans to structure a “fire as a management tool” adaptive management research effort, involving numerous organizations in the region.

Next Steps:

- SREL will post the presentations given at this workshop on the workshop website (Collins).
- ERDC and SREL will publish a special report summarizing the workshop (Collins, Goran, Balbach).
- Briefing to the SENRLG (Rush).
- Georgia and South Carolina DNR, supported by ERDC, will develop a concept document for the gopher tortoise and associated species conservation agreement, then staff it to all interested participants (Harris, Balbach, others).
- Fort Benning will plan for the first “Fire Along the Fall Line” workshop (Brent, Larimore).
- ERDC and SERDP will develop a plan for an adaptive management research effort on controlled burning, to be considered as part of the next phase of the SERDP Ecosystem Management Project (SEMP). (Holst, Goran).
- Fish and Wildlife Service, ERDC, Southeast Regional Coordination Office, Georgia DNR, and others will coordinate with Legacy Resource Program managers to see if a 2005 Legacy project can be structured to help provide habitat analysis to support gopher tortoise (and associates) conservation agreement goals.

SEMP Technical Advisory Committee Meeting

April 26-27, 2005 Arlington VA

Welcome, Review of Agenda, and Meeting Objectives (Bob Holst)

Dr. Bob Holst, SERDP Conservation Program Manager, opened the meeting with a review of the February 2005 SEMP strategy workshop. He then emphasized that the goals of the April Technical Advisory Committee (TAC) meeting were to continue the planning process for SEMP for the next 5 years and to redefine the mission and responsibilities of the TAC. A brief on the Defense Coastal/Estuarine Research Program (DCERP) was also given and related in context to the structure of SEMP.

Changes in SERDP/ESTCP (Brad Smith)

Mr. Brad Smith, SERDP Executive Director, spoke to the long-term investment changes in management and organization that SERDP and ESTCP are undergoing, which will affect SEMP. He noted that SEMP projects will report to SERDP as individual projects, rather than under the CS-1114 umbrella, and that each project will be treated as other SERDP projects are with respect to In-Progress Reviews, reporting, etc.

Introductions, Review of Notebook, and Updates (Bill Goran)

Mr. Bill Goran called for introductions from the TAC and audience. He then thanked the TAC for participation in an additional meeting in February, and to HGL, Inc. for compiling and editing the SEMP Strategy document. The notebook provided to each TAC member was then reviewed for content (contained agenda, project summaries, and SEMP publication list). He spoke to the 2nd Partners Along the Fall Line Workshop, highlighting two major themes that were identified: preservation efforts for sensitive species and prescribed fire management.

Restructuring Considerations for the SERDP Ecosystem Management Project (Bill Goran)

SEMP is currently at a midpoint in completing its restructuring objectives. The remaining “way forward” steps include: 1) briefings to Fort Benning, the regional Installation Management Agency (IMA), and the SE Environmental Coordination Office, 2) presentation to the SERDP Scientific Advisory Board (SAB) in September 2005, and 3) miscellaneous restructuring efforts occurring throughout this time frame. The RAND report identified several recommendations for improving SEMP management, which both the SEMP TAC and Fort Benning have made progress toward implementing. In response to these recommendations, SEMP managers have begun developing a strategic plan, balancing the SEMP research portfolio, improving quality assurance/quality control, addressing SEMP management staffing needs, linking the SEMP approach more strongly to installation needs, and implementing improved metrics.

The SEMP Strategic Workshop, held in Columbus, GA, during February 2005, was a key step toward initiating and implementing these structural changes. Sustainable watersheds and forest habitats were identified at the workshop as two important investment priorities for SEMP, as they will serve to unify and integrate the research as well as provide important benefits to the Fort Benning land managers. Furthermore, Mr. Goran's review of the March 2005 Partners Along the Fall Line Workshop highlighted additional opportunities for establishing partnerships, integrating research, increasing tech transfer, and facilitating management for all Fall Line/Sandhills installations. Several slides were also shown to highlight how SEMP works in the broader scheme of research at Fort Benning and beyond, further demonstrating how regional partnerships are needed between SEMP and additional research programs (e.g., Legacy Resource Management Program, Army Environmental Technology Program, Fort Benning, etc.).

SERDP & ESTCP Management Structure (Brad Smith)

Mr. Brad Smith continued the meeting with a discussion on the current restructuring of SERDP and its sister program, the Environmental Security Technology Certification Program (ESTCP). Sustainability of ranges/range operations and the reduction of current and future liabilities were identified as the two most prevalent environmental drivers for the military. The new thrust areas for SERDP and ESTCP (Environmental Restoration, Sustainable Infrastructure, Weapons Systems and Platforms, and Munitions Management) are compatible not only to these environmental drivers, but to the overall goals of SERDP, ESTCP, Congress, DoD, and the current Administration. Furthermore, Base Realignment and Closure (BRAC) will lead to extra stresses on DoD lands, and this new structure should promote better management of these lands.

Potential SEMP Changes (Bill Goran)

Mr. Goran continued the meeting by discussing the potential changes to SEMP and outlining the transitions occurring in research infrastructure, integration and infusion, organization, and management structure. The biggest of these changes will be a shift from having a project manager to a Chief Scientist, whose responsibilities will include integrating the research agenda and liaising with the SE Regional Coordination Office to facilitate region-wide integration and tech transfer. An Adaptive Management/-Technology Infusion Coordinator will also be added as part of the on-site team, and be funded equally by SEMP and Fort Benning. Finally, a Host-Site and Monitoring Coordinator will be included as part of the on-site team, and will help enhance the delivery of information.

The Way Forward (Projects) (Bill Goran)

Mr. Goran also discussed changes to project reviews, noting that the SERDP Technology Thrust Area Working Group (TTAWG) (now STC) and SAB will now see each individual project. This change was made in response to complaints from both committees. The STC will begin reviewing SEMP projects annually as part of SERDP's In-Progress Reviews, and the SAB will only see the individual projects upon their inception. This lead to the question of what exactly constitutes a core SEMP project. Is it a project on Fort Benning that covers sustainability of watersheds and forest habitat? Does it respond to a SERDP Statement of Need? Is it funded in whole or in part by SERDP? Is it a project within the Southeast? The discussion did not answer this question entirely.

Q&A/Plan Discussion

For the afternoon session, John Rupnik and Jeff Marqusee presented the vision for the Chief Scientist within SEMP (see Figure 3-1). The floor was then opened for questions, concerns, and discussion among the meeting participants.

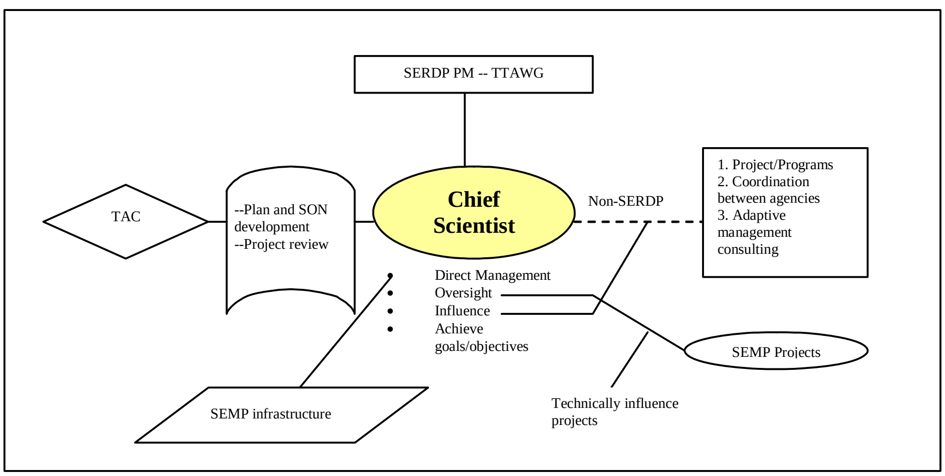

Figure 3-1. Diagram drawn at meeting to illustrate the role of Chief Scientist.

Most of the discussion focused on the roles and responsibilities of the Chief Scientist. It was agreed that Lee Mulkey, the individual chosen to fill this position, would dedicate approximately 60 percent of a typical workweek to his Chief Scientist duties and that he would work from home, commuting to Fort Benning as needed. This scenario was deemed feasible by the TAC since his staff, including the Host-Site/Monitoring Coordinator and the Adaptive Management/Technology Infusion Coordinator, will be on-site and report directly to him. This scenario would also allow the Chief Scientist to focus more on the science and the synthesis of research and results from the entire Fall Line region, two roles the TAC felt were critical to this position.

These new changes, although similar to the old SEMP management structure, will bridge the disconnect between the individual projects and SEMP as a whole. The new structure clearly provides for project oversight and clarifies the communication lines between researchers and managers, ensuring that results get to the right people right away.

There was also some brief discussion on how the U.S. Army's Construction Engineering Research Laboratory (CERL) would be affected by these changes. The TAC agreed that CERL will no longer hold a management position like they currently do, which will remove the conflict of interest. However, the SERDP Program Office will allow the U.S. Army's Engineering Research and Development Center (ERDC) to continue to bid on SONs.

The focus of the discussion ended on the new function of the TAC. With SEMP's new structure, and the annual project reviews being assigned to the STC, the TAC's mission will shift to providing a more holistic view of where we are with the state of the science and identifying important research and data gaps. Future synthesis responsibilities will be delegated primarily to the Chief Scientist. With their new mission, the TAC will function in developing SONs and reviewing proposals once peer review has been completed. Mr. Smith mentioned the possibility of having the SEMP umbrella project brief the TAC and STC together; a strategy that has proven successful in other SERDP thrusts. However, this possibility was not finalized at the meeting.

Project Evaluations

SEMP Integration Project, Dr. Virginia Dale—ORNL

Green – Project is on track. There are some minor concerns.

Rationale: The TAC had some concerns with the project's validity and terminology.

General Comments: The purpose of the presentation was to address issues raised during the September 2004 TAC meeting.

TAC Discussion and Comments:

1. There is some concern with some of the terminology chosen (e.g., desired value, marginal value, undesired value), as they invite misuse and misinterpretation.
2. SEMP management should not assume this method is the sole method for addressing indicator integration. Other models have proven successful and should be evaluated as needed, as some require less sophistication.
3. There is uncertainty as to the level of importance of the entire indicator project, its usefulness to Fort Benning and the other Fall Line installations, and its efficacy in decision-making.
4. Since Fort Benning does not share the same geography as the other Fall Line installations, there is a need to identify the optimal conditions for utilizing these indicators and transferring this technology throughout the Fall Line.
5. This model can assist SEMP in reaching some of its next steps, specifically in watershed analyses. There exists the potential to understand what effects additional sediment and nutrient loading is having on Fort Benning's aquatic systems.
6. Dr. Dale's model uses a modified Delphi approach. State transition models use a strict Delphi approach. The advantages and disadvantages of each need to be clarified.
7. Streams and landcover are both gross indicators that should be incorporated into the model.

TAC Recommendations:

1. Link an indicator to a specific management activity in order for it to be useful to the Installation.
2. Remain consistent with terminology through the project's completion, and allow peer reviewers to catch the concerns with the terminology prior to publication.
3. Coordinate with Fort Benning land managers to achieve consistency with land management categories, designations, and graphics.

4. Rework the "Land management goals and endpoints" map. Distinguish those areas we are trying to restore to pristine conditions from those areas where rehabilitation is sufficient.

Action Items:
1. Dr. Joel Brown is to write up a description of what the ideal endpoint of this project should be, including comparisons to similar indicator integration models.

SEMP Ecosystem Characterization & Monitoring Initiative (ECMI), Dr. David Price and Mr. Mark Farr—ERDC

Green – Project is on track. There are some minor concerns.
Rationale: The TAC was pleased with the progress to date.

TAC Discussion and Comments:
1. The Chief Scientist will oversee this monitoring plan and have some ownership of that data.
2. There is a need for clarity on how the stream monitoring data will fit into the ECMI.
3. The priority locations for citing meteorological stations now and in the future are in the Digital Multipurpose Range Complex (DMPRC).

TAC Recommendations:
1. Forestry surveys should occur across all land uses, in both harvested and non-harvested areas.
2. Soil stratification should be incorporated into the design of the stream monitoring plan.
3. The Chief Scientist will need to take a critical look at this project and determine its place in the new path forward for SEMP.
   a. Sampling for stream monitoring efforts needs to be validated by showing annual comparability.
   b. All future work needs to be coordinated with the Chief Scientist.
   c. The Chief Scientist needs to attend the June 2005 meeting at Fort Benning.
4. There should be in-house control of the monitoring to ensure that the same people are doing the work.
5. The ECMI presentation needs to include a graphic that depicts everything being monitored at that time.

Action Items:

1. Determine the feasibility of MODUS for terrestrial ecosystem monitoring.

Background of Lee Mulkey

At this point in the meeting, Mr. Lee Mulkey, proposed new Chief Scientist/Project Director for SEMP, gave a brief description of his background, including his many years with the Environmental Protection Agency (EPA). He also described his philosophy and approach to this position. Mr. Mulkey will present this information in written form to the SERDP Program Office, along with his vision for executing SEMP's new strategic plan.

Biogeochemistry Proposal (Bob Holst, Bill Goran)

Green – Project should be allowed to move forward.

Rationale: This project will cover entire Fall Line region and clearly fits the direction of the restructuring of SEMP.

TAC Discussion and Comments:

1. The Scientific Advisory Board had many questions concerning this potential project.
2. This is pushing the state-of-the-art for the Century model.
3. The TAC was disappointed in the number of proposals received from the statement of need released addressing biogeochemical cycles.
4. The TAC agreed that this project should go ahead and begin Phase I. Mr. Smith agreed to support and fund the project.
5. This project will be the first SEMP project not grouped under the CS-1114 umbrella. It will be assigned its own project number, and the PI will brief the SAB and STC as any other SERDP project would.

TAC Recommendations:

1. The proposal needs to modify the underlying model so as to consider a greater soil depth in its calculations.
2. Start with only Phase I, after which there will be a Go/No-Go decision.

Fort Bragg Proposal (Bob Holst)

The proposal is not complete enough to warrant funding.

Path Forward

The TAC meeting closed with further discussion on SEMP's path forward. The TAC agreed that the Chief Scientist should be more closely involved with the projects and the Principal Investigators (PI). It was recommended that the Chief Scientist hold informal annual meetings with the PIs to collaborate, share information, and discuss what is working and what is not working.

The Chief Scientist was charged with creating SEMP's approach for the next 5 years and its vision for 5 years and beyond. This vision should include an independent assessment to trace previous research results and corresponding management actions, and an assessment of sustainability in terrestrial and aquatic environments, and should be presented in a form that Fort Benning can work with. This product should also provide for the implementation of technology transfer, including outsourcing of the meteorological stations to a broader network and collaborating with Rusty Bufford of Fort Benning on satellite imagery data.

The TAC agreed that SON development for FY 2006/2007 funding was a critical issue. Fort Benning staff will now be involved in both SON development and proposal review. Furthermore, the results from the upcoming water quality meetings, the SEMP Strategic Workshop, and the Partners Along the Fall Line Workshop should be analyzed to develop SONs for FY 2007 and FY 2008. The TAC agreed that this should occur in the next 60 days. Finally, new SONs will now include the Chief Scientist's vision, which will attract proposals more closely related to the SONs' intended research.

With respect to the FY 2006 SON related to Longleaf Pines, Mr. Smith and Dr. Holst will review the proposals first to determine if the research will fall under the SEMP umbrella. The proposals will then go to the TAC for review, with any TAC member excusing himself or herself should a conflict of interest arise.

Action Items:

1. The Chief Scientist will draft the SEMP approach for the next 5 years and its vision for the next 5 years and beyond. In this document, include a provision for the implementation of technology transfer, including meteorological station data, and satellite imagery. The content of Chapter 2 of this Report reflects the completion of this item.

XVII International Botanical Congress

July 17-23, 2005, Vienna, Austria, Europe

This summer Hal Balbach presented an oral presentation on July 20th 2005 at the International Botanical Congress:
"The relationship between landscape disturbance and biodiversity using ecological indicators and a site comparison index."
A. J. Krzysik, H. E. Balbach, D. A. Kovacic, J. H. Graham, M. P. Wallace, J. J. Duda, J. C. Zak, D. C. Freeman, J. M. Emlen.
The relationship between habitat disturbance and biodiversity has strong implications for both ecological theory and land conservation strategies. Research to identify ecological indicators of landscape disturbance was conducted in the complex Fall-Line Sandhills physiographic ecotone of southeastern USA (Fort Benning, Georgia). Forty sites were selected representing the full range of military training disturbance and upland vegetation communities. Seven ecological indicators were analytically identified, standardized, and weighed by statistical criteria to develop a composite Site Comparison Index (SCI). SCI transect scores were grouped into five ordinal disturbance classes. Within this disturbance gradient, 33 metrics of biological diversity were statistically evaluated (16 for ground cover, 9 for trees, and 8 for ants). Diversity metrics included: species richness, abundance, dominance, and Simpson, Shannon, Brillouin diversity and evenness indices. The effect of disturbance on biodiversity varied dramatically with the metric employed. A number of patterns substantiated the intermediate disturbance hypothesis.

SEMP SAB Meeting

September 12-16, 2005 Arlington, VA
Overview of 2005 Efforts

A. Research Projects:
All five of these initial SEMP research projects are completed, and researchers have submitted final reports. Each research team is also briefing their findings to Fort Benning staff, although some of these briefings are still being scheduled. While the projects are complete, each of the research teams is still actively writing and submitting journal articles, and the status of publications is updated each month (see Appendix B for a listing of reports and publications for each project).

B. Research Integration Effort:
During the Spring 2002 meeting, the SEMP Technical Advisory Committee (TAC) recommended an effort to "integrate" findings from the different research projects included within SEMP. Virginia Dale of Oak Ridge National Lab, who leads one of the indicator projects, was asked to lead this effort. A plan was developed for a 2-year effort, to be conducted during 2003 and 2004, but a mapping phase was added, to make the analysis matrix spatially explicit, and this phase has extended the integration effort into 2005.

During 2003, this effort involved a process for each SEMP research team to nominate and document candidate indicators, and a process to characterize the land use and land cover types at Fort Benning. A workshop was held, during Sept 2003 at the University of Florida, to evaluate these emerging indicators and to review and revise indicator review criteria that had been published from earlier SEMP deliberations in the journal *Ecological Indicators* in 2002.

A system of land-use categories was developed after extensive discussions with the Fort Benning resource managers and email interactions with the research teams. It was finalized in a workshop, held in May 2003 at Fort Benning and involving installation staff. Each research site has since been assigned to a category within the land-use matrix.

During 2004, these indicators were analyzed to determine how well they predicted differences between the land-use types, and the overall list of indicators was reduced, based upon the established criteria for indicators. During 2005, the land-use categories are being translated to GIS map layers for the entire base. The next step is to use these indicators within a monitoring program to determine if conditions are moving towards the intended goals for each landscape element. These selected indicators, the new maps and the initial monitoring data results will be incorporated, as appropriate, into the Fort Benning Integrated Natural Resources Management Plan (INRMP), which will be revised in 2006.

C. Site Comparison Indices
One of the problems faced by SEMP, has been the ability to compare data collected at different sites from different teams, using relatively subjective criteria to describe the land use condition (light, moderate, or heavy). These descriptors have not been adequate to fully describe the condition

gradient, and data available from the installation regarding usage information for areas within the base are at too course a scale (large training areas, that are each characterized by a wide range of use condition) to resolve this problem.

In 2001, the SEMP TAC recommended that the SEMP Program Manager initiate an effort involving the research teams, the installation staff, and the monitoring team, to establish criteria that could be used to describe a condition gradient relevant to the full range of use conditions at the base. Two different indices are planned: the Terrestrial Site Comparison Index and the Watershed Comparison index. During 2002, the SEMP Research Coordinator, Dr. Harold Balbach, led an effort to establish the Terrestrial Index, and then, during 2003, several research teams, led by the Prescott Team, collected and analyzed site data along a “condition gradient” as defined by these new data sets. During 2004, the terrestrial site comparison indices were captured in a field manual that included detailed methodologies. This manual will be field tested in autumn 2005. Also in 2004, a watershed comparison index was described. The development and application of the Site Comparison Index was presented to the XVII International Botanical Congress in July 2005.

D. Terrestrial Productivity Statement of Need
A new statement of need was drafted in 2003 for the 2005 SERDP Solicitation announcement. Several proposals were submitted against this solicitation, and two of these proposals were recommended for further consideration from the peer review process. After review and discussion with the SEMP TAC members, the SEMP Program Manager, and the SERPD Program Office, a decision was made to recommend funding for a three year project proposed by Dr. Shanguang Liu and Dr. Larry Tieszen of the USGS EROS Data Center entitled Developing Terrestrial Biogeochemical Cycle models for Fort Benning Ecosystems.

Monitoring Program

The monitoring program was planned during 1998, with data collection starting in 1999. Since 1999, data has been collected at networks of weather, groundwater, and surface water stations, and imagery has been collected and analyzed every other year (’99, ’01, ’03, and ’05). Aquatic biota is also being collected using Rapid Biological Protocol (RBP) in a manner consistent with RBP data across the state of Georgia. In 2004, an expanded analysis phase was added, to ensure that the data from the monitoring program is provided, with trends and reference data, to the host installation and to current and future research teams. The monitoring team has employed a biostatistics expert, from Louisiana State University, to assist in developing and evaluating analysis and QA/QC procedures.

In 2005, two of the ten ECMI weather stations are being upgraded to link to a statewide weather monitoring network managed by the University of Georgia. This linkage will allow Fort Benning users to obtain real time data on weather conditions down range, and allow regional managers to have more comprehensive weather data for the far western region of the state.

This information is important for rating safety conditions for soldiers training in the field. In addition, SEMP monitoring data is being integrated into an overall monitoring plan related to potential impacts of construction and operation of a digital multi-purpose firing range scheduled for construction in 2005. Starting in 2005 and continuing in 2006, a series of technology transfer workshops will be held to transition monitoring responsibilities for the stream water stations and the imagery analysis to Fort Benning personnel.

SEMP Knowledge Management and Repositories

During 2002, a major upgrade was initiated for the SEMP Data Repository (SDR), to increase flexibility, improve the user interface, and provide multiple levels of security and access. The work was completed in the summer of 2003, and the revised site is now operational; most FY 2004 and early FY 2005 activity has been routine updating. All of the monitoring and research data is entered into this repository, and the research integration project will conduct analysis based upon the data in this repository. In addition, there is an extensive set of data for the host site. The public can now visit this site (http://sempdata.cecer.army.mil) and examine the site metadata. Access to the actual data sets requires interested parties to request a password from the SDR manager. Acquiring a public-access login and password for the site is currently an automated process. There are now 104 registered users. During this fiscal year, the site has been equipped with tools for indexing its contents in the Open Archive Initiative (OAI) format as an operational study into methods for provide interoperable metadata to facilitate indexing, sharing, and searching of contents. A database of SEMP-related documents and projects has been designed and constructed and is being merged with the current holdings of the SDR. Other ongoing work to the SDR focus on improving the web interface, security model, improving the metadata classification, and adding web-tools for update and access of SDR holdings.

RAND Review and Subsequent Restructuring Plans

During 2004, the RAND Corporation conducted a comprehensive review of SEMP, which was presented to the SERDP Scientific Advisory Board in September 2004, then to the SEMP TAC a few weeks later. The final version of this report, authored by B. Lachman, N. Clancy and G. Cecchine, was submitted to the SERDP Program Office in November 2004. This report identified the need for a new strategy to guide future SEMP efforts, and the need for increased value from SEMP to Fort Benning and other bases.

In January 2005, Fort Benning held a science and technology needs workshop to help define ecosystem management problems that SEMP might help them address. Then in February 2005, SERDP sponsored a SEMP "way forward" workshop, which included Fort Benning staff, SEMP TAC members, SERDP staff, and several invited regional and national ecosystem management experts to help devise new approaches for SEMP that would be responsive to these newly articulated Fort Benning needs.

Draft restructuring plans for SEMP were then developed and presented to the SEMP TAC and to the SERDP Conservation Trust Area Working Group in April 2005. After review from these groups, the plans were revised and organized into a white paper, which lays out a future strategy for SEMP. In this strategy, the gap between SEMP science and technology investments and Fort Benning ecosystem management activities is addressed by a two-phase process of technology/knowledge assessment and then technology infusion management. A new Chief Scientist position will replace the SEMP Project Manager and this Chief Scientist will manage this assessment process, while a new, full time, on-site technology infusion coordination is already working with the Fort Benning staff to help interpret and transition the science knowledge and technologies emerging from SEMP and other SERDP and Army research efforts.

Range Construction

During 2004, the SEMP Team supported Fort Benning in responding to challenges relating to characterizing and monitoring the impacts of the planned new Digital Multi-Purpose Range Complex (DMPRC). A workshop was held in July 2004 at Fort Benning to gather input from various

SEMP (and associated) teams, and a report on the region impacted by the range has been prepared for Fort Benning. In addition, the SERDP Program office has provided additional resources to Dr. Pat Mulholland of Oak Ridge National Lab to ensure that the impacted area is sufficiently characterized preceding this major construction event (scheduled to begin in December 2004). These efforts have continued in 2005, and a workshop held in June 2005 at Fort Benning provided valuable information for Fort Benning on the conditions of surface waters impacted by range construction. Fort Benning is receiving some additional new missions, and several other new ranges are being planned for construction. This DMPRC monitoring effort will also be used to help "predict" the impacts of other ranges on surface streams status and on aquatic habitats and improve the assessment and mitigation plans for each of these ranges.

SEMP Technical Advisory Committee

The SEMP TAC met in April in Arlington, VA, and a second meeting is scheduled for October 3-4 on post at Fort Benning, GA.

Current TAC members include the following: Dr. William McDowell of the University of Vermont, Dr. Thomas Greene of The Nature Conservancy, Dr. Joel Brown of New Mexico State University and USDA, and Dr. Michael Miller of the University of Chicago/Argonne National Laboratory, Dr. Louis Kaplan of the Stroud Water Research Center, Dr. Kay Kirkman of the Jones Ecological Research Center, Dr. Neal Burns of the Environmental Protection Agency, and Dr. Roger Dahlman of the U.S. Department of Energy. Dr. Mary Barber serves as an ex officio member of the TAC.

American Society of Agronomy Meeting

November 6-10, 2005, Salt Lake City, UT

William Goran presented "Across the Fence Line: Challenges Facing Department of Defense" with Hal Balbach and Bob Barnes. The following abstract describes the presentation:

The Department of Defense operates facilities across the United States and in many host nations. These facilities impact their surrounding regions, and, in turn, are impacted by their regions. During the 1970s and 1980s, joint planning efforts were initiated through a program of the Defense Office of Economic Adjustment (OEA) to encourage communities to work with defense bases to "plan" across their fence lines. Frequently, these plans revolved around noise issues, and relied upon noise contour maps generated from analysis of aircraft flight paths and blast noise patterns emerging from installation mission activities. In the past decade, the Department of Defense has become even more proactive in addressing across the fence line issues, largely because of growing constraints on mission activities. Installations have been partnering with neighbors to preserve habitat across shared ecoregions, to avoid the increase of incompatible land uses along installation boundaries, to share resources such as utilities, housing and recreational resources, and to plan “sustainable” uses of dwindling regional resources for future years. This presentation will examine efforts to provide data, information and procedures for enhanced “across the fence line” planning between installations and surrounding communities and stakeholders – and identify likely future directions and trends

SERDP Symposium

November 28 - December 1, 2005, Washington, DC.
At this Symposium, a special effort was made to assemble “Final Report” posters from all of the original SEMP research projects. Each of the PIs did contribute a poster, as follows:

CS-1114A
Development of Hydrologic, Soil, and Vegetation Indicators of Land Condition for Natural Resources Management
Dr. Ramesh Reddy (University of Florida)
Dr. William DeBusk (University of Florida); Dr. Wendy Graham (University of Florida); Dr. Jennifer Jacobs (University of New Hampshire); Dr. Deborah Miller (University of Florida); Dr. Andrew Ogram (University of Florida); Dr. Joseph Prenger (Florida Fish and Wildlife Conservation Commission); Dr. Suresh Rao (Purdue University); and Dr. George Tanner (University of Florida)

A multidisciplinary study was conducted at Fort Benning, Georgia (USA), under the auspices of the SERDP Ecosystem Management Project (SEMP), to evaluate a suite of hydrologic, soil, and vegetative parameters as potential indicators of ecological change, in support of resource management activities on military installations in the southeastern United States. The soil, vegetation, and hydrologic parameters (potential indicators) that were most closely correlated with pre-determined site disturbance levels (low, moderate, severe) were those that reflected loss of vegetation biomass and community structure, disruption and/or compaction of soil, and loss of soil A horizon (and soil organic matter) in uplands; and accelerated sedimentation of clay and sand in wetlands. Promising soil biogeochemical indicators of site disturbance included total organic carbon (C), microbial biomass C, soil microbial respiration, microbial enzyme activity, and microbial community composition. Several watershed hydrologic parameters were correlated with intensity of military land use, including stream chemistry, particularly total organic C and total Kjeldahl nitrogen (TKN), and changes in storm-based hydrologic indices, such as baseflow index, bankfull discharge, response lag, and time of rise. Density of herbaceous vegetation (ground cover) and present/absence of various plant species were related to site disturbance under military and non-military land uses. Multivariate analysis, principal component analysis, and canonical correspondence analysis were utilized to derive combinations of factors that may be used as indices for determination of ecological change.

CS-1114B

Development of Ecological Indicator Guilds for Land Management: Final Summary

Dr. Anthony J. Krzysik

Co-Performers for this research: Dr. David A. Kovacic; Dr. John H. Graham; Dr. John C. Zak; Dr. Harold E. Balbach; Dr. D. Carl Freeman; Dr. John M. Emlen; Dr. Jeffrey J. Duda; Dr. L.M. Smith (deceased)

This research is a SERDP-SEMP funded project "Development of Ecological Indicator Guilds for Land Management" (CS 1114B). The research presented here consisted of: 1) two separate phases to identify environmental metrics and guilds (i.e., groups) of Ecological Indicators (EIs) of landscape disturbance, 2) the statistical integration of individual indicators and indicator systems, and 3) their application to develop a Site Condition Index (SCI). The overall objective of the research was to develop an integrated set of Ecological Indicators to: quantify habitat conditions and trends, track and monitor ecological changes, provide early-warning or threshold detection, and provide guidance for land managers based on ecological realities and statistical rigor.

In Phase I research, a very broad range of potential physical, chemical, physiological, community, and ecosystem indicators were selected for evaluation in the Fall-Line Sandhills physiography at Fort Benning, Georgia. Nine sites were selected in adjacent watersheds of upland Mixed Pine-Hardwoods, three sites each in High, Medium, and Low disturbance classes, based on current and past U.S. Army mechanized infantry training activities. Seven Ecological Indicator Systems were identified that statistically differed among the three disturbance classes or characterized ecosystems: Habitat Metrics, Ground Cover (includes shrubs) Communities, Tree Communities, Soil Chemistry, Microbial Community Dynamics, Ant Communities, and Developmental Instability of a perennial forb (*Cnidoscolus stimulosus*).

Phase II research further evaluated these seven indicator systems at 40 sites (including the original 9) selected throughout the installation to represent the full range of upland plant communities and landscape disturbance at Fort Benning. Site selection was based on 8 GIS databases, site criteria and data from other SEMP research teams, and extensive field ground-truthing. The 40 sites were classified into 10 landscape disturbance classes, based on pre-data collection visual assessment of military training damage to vegetation and soils. The multivariate integration of derived EIs is demonstrated along the 10-class disturbance gradient.

Seven individual EIs were statistically selected on the basis of their responses along the 10-class disturbance gradient, and weighed by statistical criteria to develop the final composite SCI for individual sample transects: Soil A-Horizon Depth, Soil Compaction, Soil Organic Content, Litter Cover, Canopy Cover, Tree Density, and Basal Area. A histogram of SCI scores versus the SCI ranked sample transects displayed a sigmoid logistic decay curve. The continuity of the curve demonstrated that the complete upland disturbance gradient was characterized at Fort Benning. Although these analyses demonstrated robust results, additional assessments are required at a greater variety of ecosystems, physiographies, and ecoregions.

CS-1114C

Ecological Indicators for Resource Management

Dr. Virginia H. Dale

Dr. Dan Druckenbrod, Dr. Pat Mulholland, and Lisa M. Olsen (Oak Ridge National Laboratory); Dr. Jack Feminella and Dr. Kelly Maloney (Auburn University); and Aaron Peacock and Dr. David White (University of Tennessee)

Studies at Fort Benning funded by SERDP support our hypothesis that a suite of metric is useful for measuring changes in ecological conditions.

That suite should include landscape metrics of current and historical conditions, watershed indicators, and plot-level metrics of changes in vegetation and soil microbial biology. The most useful landscape metrics were total edge (m), landscape composition, number of patches, descriptors of patch area, nearest neighbor distance, and clumpiness. Changes in these metrics from 1827 (using a map developed from witness tree data) to 1999 (based on Landsat imagery) document that land cover has become more fragmented. A number of physical, hydrological, chemical, and biological characteristics of streams were good indicators of watershed-scale disturbance at Fort Benning. Stream channel organic variables were highly related to disturbance. The degree of hydrologic flashiness and bed stability were good indicators of watershed-scale disturbance. Among the stream chemistry variables, the concentrations of total and inorganic suspended sediments during baseflow and storm periods were excellent indicators of disturbance, increasing with increasing disturbance levels. In addition, baseflow concentrations of Dissolved Organic Carbon (DOC) and Soluble Reactive Phosphorus were good disturbance indicators, declining with increasing disturbance levels. Stream benthic macroinvertebrates also served as good indicators of watershed-scale disturbance. A multimetric index designed for Georgia streams (GASCI) consistently indicated watershed disturbance and exhibited low seasonal and annual variation. Low diversity of fish precluded use of traditional measures (i.e., richness, diversity); however, *Pteronotropis euryzonus* and *Semotilus thoreauianus* were negatively and positively related to disturbance, respectively. Finally historic land use explained more variation in contemporary bed stability and longer-lived, low turnover taxa than contemporary land use suggesting a legacy effect on these stream measures. Furthermore, the soil microbial community of a longleaf pine ecosystem at Fort Benning, Georgia, responds to military traffic disturbances. Increasing traffic disturbance decreases soil viable biomass, biomarkers for microeukaryotes and Gram-negative bacteria, while increasing the proportions of aerobic Gram-positive bacterial and actinomycete biomarkers. Together these indicators reveal information about changes at critical spatial and temporal scales. For specific management questions, the resource managers are urged to select from the suite of indicators analyzed in this research as well as those presented by other researchers for those indicators that best meet the criteria for the task.

CS-1114D

Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications

for Soil Quality, Ecosystem Recovery, and Sustainability
Mr. Charles T. Garten, Jr. Oak Ridge National Laboratory

Research was conducted on soil carbon (C) and nitrogen (N) dynamics at Fort Benning, GA, from October 1999 to June 2004. The objectives of the work were to (1) develop a better understanding of the effects of disturbance on key measures of soil quality, and (2) determine if there are thresholds of soil quality that potentially affect terrestrial ecosystem recovery or sustainability. The principal findings from each technical objective associated with the research are summarized in this final poster report. The purpose of the first task was to investigate the effects of soil disturbance on key indicators of soil quality. We found that measurements of soil C and N are ecological indicators that can be used by military land managers to identify changes in soil from training activities and to rank training areas based on soil quality. The second technical task was to use a simple model of soil C and N dynamics to predict nutrient thresholds to ecosystem recovery on degraded soils. We found four factors were important to the development of thresholds to recovery of plant communities: (1) initial amounts of aboveground biomass, (2) initial soil C stocks (i.e., soil quality), (3) relative recovery rates of plant biomass, and (4) soil sand content. The purpose of the third task was to use a compartment model to predict forest recovery and sustainability under different regimes of prescribed fire and tree harvesting. The model-based analysis indicated that, relative to the control (i.e., no fire) and depending on fire intensity, prescribed burning with a 2- or 3-year return interval caused only a small reduction in predicted steady state soil C stocks (≤25%) and had no effect on predicted tree wood biomass. Predicted impacts of fire on forest recovery and sustainability (after harvesting) were a function of both site N status and fire intensity. The final technical task was to examine the effects of heavy, tracked vehicle disturbance on soil properties. The disturbance was accomplished by driving a D7 bulldozer through a mixed pine/hardwood forest. Results from the latter experiment suggested that the best indicators of a change in soil quality are found at the soil surface because there were no statistically significant effects of the disturbance at soil depths below 10 cm. The research was supported by the Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP) under contract with Oak Ridge National Laboratory, managed by UT-Battelle, LLC.

CS-1114E

Land management and military use effects on the ground layer of upland forests at Fort Benning

Dr. Beverly Collins

Co-performers: Dr. John Dilustro and Ms. Lisa Duncan, University of Georgia – Savannah River Ecology Laboratory

This SERDP/SEMP-funded project was conducted from 2000-2004 to evaluate the ecological effects of military training and forest management at Fort Benning, Georgia, and to determine if there are thresholds beyond which upland ecosystems cannot sustain the combined effects of forest management and military training disturbances. We compared groundlayer vegetation and nitrogen cycling in 32 mixed pine/hardwood stands that differ in soil texture (from sandy to clayey) and intensity of military training (lighter dismounted infantry vs. heavier mechanized training). These stands are managed by prescribed fire to promote longleaf pine regeneration. Prescribed burns were conducted prior to the study in 2000, and again in 2002 (1/2 of plots) and 2004. The 2002 fire reduced the soil organic layer over the two following growing seasons, but did not affect mineral soil nitrogen content; before and after the fire, stands with lighter training and clayey soil had the greatest mineral soil nitrogen. NMDS ordination of vegetation similarity (2000-2004) separated sites with sandy and clayey soil. A second 'degree of disturbance' dimension separated sites with heavier military use and more frequent fire (less species-rich, more xeric vegetation) from those with lighter military use and less frequent fire. Differences due to fire developed after the second year. Grasses, legumes, and older stages of regenerating longleaf were most abundant in sites with relatively high historical fire frequency and greater abundance of disturbance features, but fire caused mortality of tagged tree (pine, hardwood) seedlings. These results suggest that both heavier military use and frequent fire have contributed to a groundlayer rich in legumes and grasses, and like that of a longleaf ecosystem. Prescribed fire can maintain this groundlayer composition, but, over the short term, is not sufficient to cause a change in system trajectory. Further, frequent fire will not sustain longleaf regeneration if seedlings die before reaching the grass stage.

ECMI

Ecological Site Descriptions: Applications For Military Land Management

Dr. David Price, US Army ERDC – Environmental Laboratory
Dr. Joel R. Brown USDA NRCS – Jornada Experimental Range

Ecological sites are groupings of soil and landform units that have similar potential to support plant communities and respond similarly to disturbance and management. For each site, a unique Ecological Site Description (ESD) is developed that includes (1) a description of ecological processes affecting soil/vegetation relationships (2) a synthesis of research results and management knowledge to predict site responses and (3) a discussion of ecosystem services associated with potential stable states. Currently, federal land management agencies are in the process of developing guidance for implementing ESDs for on-the-ground decisionmaking as well as policy development. ESDs offer an opportunity for managers of Department of Defense lands to better organize and communicate information that serves as the basis for critical, and often controversial, decisions. In particular, when multiple potential stable states exist for each site, ESDs can improve objective setting and planning. Each stable state possesses differing values for a variety of uses (wildlife habitat, training, watershed) as well as inherent ecological properties (resistance and resilience to change). Critical points in the transition from one state to another (thresholds) can also be described to provide early warning of undesirable change and provide a trigger for responsive management. A more clearly defined objective for each site and the factors associated with change can improve the application of monitoring procedures and the assessment of management actions. Development of ESDs and the science that supports them are at a critical stage. Although the opportunities are plentiful, a substantial challenge remains in connecting and maintaining the multidirectional supply lines of research information to policy development and implementation. In particular, two issues challenge the successful development of ecological site descriptions: (1) how best to describe and convey within site dynamic processes and (2) how to extend site information beyond the plant community scale to landscape and regional applications. How these issues are addressed will determine the success of ESDs in informing and improving land management policy. Because ESDs are, for all practical purposes, the on-the-ground manifestation of our collective understanding of ecology, there is a need to closely examine how ecological, economic and social science is being organized into these decisionmaking tools. This SERDP-funded project is part of the SERDP Ecosystem Management Project (SEMP).

4 Final Report: Determination of Indicators of Ecological Change: CS 1114A

SERDP Ecosystem Management Project CS 1114A Executive Summary
Principal Investigator: Dr. Ramesh Reddy
University of Florida - with participation by Purdue University

Introduction

The goal of this research is to develop indicators of ecosystem integrity and impending ecological change that include natural variation and human disturbance. We are evaluating parameters related to properties and processes in the understory vegetation, soil and surface hydrology as potentially sensitive indicators of ecosystem integrity and ecological response to natural and anthropogenic factors. The basic premise is that soil serves as the central ecosystem component that links the quality of the terrestrial habitats (by influencing vegetation and its stability) and the aquatic habitats (via control of soil erosion and overland runoff). We have evaluated potential ecological indicators for sensitivity, selectivity, and ease of measurement. Indicator selection was based on those that 1) show a high correlation with ecosystem state, 2) provide early warning of impending change and 3) differentiate between natural ecological variation and anthropogenic negative impacts. In addition, we have attempted to determine the range of natural variation for indicator variables, and compared those with the range of values under anthropogenic, especially mission-related, influences. Our research and monitoring plan addresses the following five tasks:

- Task 1 Soil/sediment quality indicators: Identification of physical, chemical and biological variables of soil that may be used as indicators of ecological change.
- Task 2 Vegetation indicators: Identification of species and community variables of vegetation that may be used as indicators of ecological change.
- Task 3 Hydrology: Identification of aspects of surface hydrology that may be used as indicators of ecological change.

- Task 4 Stream Water Quality: Correlation of watershed hydrology and soil biogeochemistry in order to identify natural and anthropogenic influences on water quality.
- Task 5 Synthesis and Modeling.

Findings

Severe impacts to soil, vegetation, and hydrologic processes are associated with mechanized training involving tracked (tanks and Bradley) vehicles. Moderate to severe impacts also occur in several areas of non-military land use, primarily due to forest clear-cutting activities. Hydrologic and ecological impacts observed in wetlands and streams downslope from clear-cut upland areas were similar in nature to those observed in association with severe military disturbance; however, since silvicultural activities are typically shorter duration, the extent and severity of these disturbances are less and recovery more rapid than those associated with mechanized military activity. The soil, vegetation, and hydrologic parameters (potential indicators) that were most closely correlated with pre-determined site disturbance levels (low, moderate, severe) were those that reflected loss of vegetation biomass and community structure, disruption and/or compaction of soil, and loss of soil A horizon (and soil organic matter) in uplands; and accelerated sedimentation of clay and sand in wetlands. In wetland areas downslope from impacted uplands, relationships between soil biogeochemical indicators and upland impacts were less clearly defined. However, indicators that directly related to wetland soil organic matter content (and “dilution” by clay or sand) were useful in identifying sediment-impacted wetlands located below severely disturbed upland areas. The potential value of wetland soil biogeochemical properties as indicators of nutrient loading in uplands (e.g., from excessive fertilization or waste disposal) was not realized at the Fort Benning study areas, due to the nature of the ecological impacts in upland areas. Commonly observed impacts of mechanized training on soil and vegetation included:

- Disturbance or destruction of vegetation communities, including ground cover (especially litter cover), understory, and canopy vegetation.
- Disruption of soil A horizon and effective burial or dilution of biologically active topsoil with organic-poor lower horizons.
- Compaction of subsoil, reducing soil permeability and increasing runoff and erosion potential.

- Loss of A and E horizons in severely impacted upland areas, rendering soil unsuitable for supporting native plant communities.
- Gulley erosion in downslope areas, with significant sedimentation in wetlands and streams.
- Short-circuiting of watershed flow paths with increased surface runoff and decreased subsurface detention in uplands (creating hydrologic and ecological imbalances in wetlands and streams).

Accomplishments

Soil Biogeochemistry

The most promising soil biogeochemical indicators for upland areas were highly correlated with soil organic matter content and carbon (C) quality (biodegradability).

Total organic C - indicator of soil disturbance resulting from loss of topsoil (erosion) or mixing of A and E horizons.
Anthropogenic impacts on soil and ground cover in upland areas of the Fort Benning study site included (1) disturbance or destruction of vegetation, resulting in increased area of bare ground and a greater proportion of early successional species, (2) disruption of soil A horizon and effective burial or dilution of biologically active topsoil with organic-poor lower horizons, (3) increased erosion in uplands and deposition of sediment in bottomland areas, and (4) loss of soil A horizon in severely impacted upland areas. Impacts to bottomland soils were primarily associated with soil disturbance in adjacent upland areas, and typically involved accelerated deposition of clay and silt (moderately impacted areas) or sand (severely impacted areas). The primary impact of increased sedimentation, with regard to soil C and N dynamics, was dilution and/or burial of organic matter contained in the native wetland soils. For both upland and bottomland sites, the observed decrease in soil Total Carbon and Total Nitrogen with increasing level of impact was indicative of the reduction in soil organic matter content of surface horizons

Microbial biomass (as C) - indicator of the size of the labile (readily bioavailable) soil C pool.
Microbial biomass C (MBC) and soil respiration showed a significant decrease with increasing site impact, consistent with the trend observed for TC. However, changes in MBC with impact level were not directly propor-

tional to changes in TC, as demonstrated by the significant increase in MBC:TC with site impact.

Soil (microbial) respiration - indicator of the amount of bioavailable soil C.

Soil respiration rate was roughly correlated with TC concentration, as would be expected since organic C provides the metabolic substrate for soil microorganisms. Since soil respiration was determined by laboratory incubation of soil samples at a constant temperature, the measured rates represented (1) primarily microbial respiration rather than root respiration, and (2) potential respiration rates rather than actual in situ rates at the time of sampling. Therefore, soil respiration reported in this study was an indication of the size of the bioavailable pool of soil C.

Ratios of microbial biomass to organic C and respiration to biomass – relative bioavailability of the soil organic C pool.

Metabolic quotient (qCO_2), or specific respiration rate (normalized to MBC), showed a significant decrease with increasing level of impact. In our study, it was apparent that decreasing qCO_2 with increasing site impact was related to substrate bioavailability, and was not a response to environmental (external) stress. Although the biochemical processes governing the relationship between qCO_2 and soil impact or condition are not known with any certainty, our study results suggest that this parameter may be a useful indicator of ecological condition or change, primarily for upland areas. The ratio of microbial biomass C to soil organic C (a.k.a. microbial quotient) has been related to soil C availability and the tendency for a soil to accumulate organic matter. Based on combined results of Phases 1 and 2 of this study, both DOC:TC and MBC:TC were found to be relatively good indicators of soil "quality" in upland areas, as related to site impacts or ecological condition. The potential value of the DOC:TC parameter as a robust indicator is beyond the scope of this study, for neither soil quality nor ecological condition can be determined solely from these results. The MBC:TC parameter, on the other hand, has been widely used as an indicator of bioavailability of soil organic C.[1]

[1] Anderson, T.-H., and K.H. Domsch. 1989. Ratios of microbial biomass carbon to total organic carbon in arable soils. Soil Biol. Biochem. 21:471-479. Sparling, G. P. 1992. Ratio of microbial biomass carbon to soil organic carbon as a sensitive indicator of changes in soil organic matter. Aust. J. Soil Res. 30:195-207.

Relative bioavailability of soil C was higher in disturbed areas due to depletion of older, more stable soil organic matter.
The response of qCO_2 to soil disturbance was consistent with the responses of DOC:TC and MBC:TC, all of which suggest that resource (organic C) quality increased with soil disturbance, i.e. there was a lower proportion of recalcitrant soil organic matter, even as total soil C storage decreased with increasing disturbance.

Beta-glucosidase activity - indicator of the amount of bioavailable soil C.
β-glucosidase did distinguish the three levels of impact in bottomland transects, perhaps indicating a higher ratio of available carbon to TC at intermediate levels of disturbance. Separation of moderate from low and severe impacts by β- glucosidase was less effective in upland soils.

Methanotrophic bacterial communities differ in highly impacted bottomlands.
Terminal restriction fragment length polymorphism (T-RFLP) analysis of *pmoA* genes was applied to samples taken from transects located in upland and bottomland sites within the two watersheds. Principal components analysis (PCA) revealed that T-RFLPs from upland and for the most part bottomland samples clustered together in both watersheds. However, some Bonham Creek bottomland T-RFLPs clustered within the upland cluster, suggesting mixing of upland with bottomland soils.

Depth (thickness) of the A horizon - indicator of soil disturbance resulting from loss of topsoil (erosion) or mixing of A and E horizons.
A-horizon depths decreased with increased level of disturbance category: bottomland sand-loam, Low to Medium; upland clay, Medium to High; upland sand, Low to Medium to High.

Vegetation

Vegetative indicators that most accurately reflected the impacts of military training were:
Percent cover of herbaceous vegetation (ground cover and litter cover), or in cases of more severe impacts, canopy cover.
Woody plants did not differentiate well among the disturbance levels; however, there was a trend of decreased overstory canopy cover with increased disturbance. Herbaceous vegetation composition on severely disturbed sites segregated from low and medium disturbances but no segregation was found between the two lower levels of disturbance. Chronic,

landscape-scale disturbances have resulted in a very resilient flora. Coverage of bare ground and plant litter may best serve as indicators of disturbance.

Plant species present only in severely disturbed sites identify the highest degree of disturbance.
Relative cover of *Rubus* sp. and *Rhus copallina* may be an important indicator of a shift from moderate to severe conditions. These two species are prolific seed producers, enhancing their ability to colonize disturbed sites, and they appear to withstand physical disturbance once established. Those herbaceous species most closely associated with severely disturbed sites were: *Digitaria ciliaris*, *Diodia teres*, *Stylosanthes biflora*, *Aristida purpurescens*, *Opuntia humifusa*, *Haplopappus dirasicatus*, and *Paspalum notatum*. Solid stands of *Paspalum notatum*, an exotic species of grass, occurred on sites that had been totally denuded in the past, and probably was planted to reduce erosion.

Plant species indicating various stages of recovery from severe disturbance were identified that may be useful in tracking the progress of restoration efforts in highly-impacted areas.
Herbaceous species composition and cover varied more with stand age than understory woody species.
Species richness did not differ among age classes for either woody or herbaceous species, while species distribution and abundance did. *Bulbostylis barbata* and *Pityopsis* spp. were identified as indicators of younger sites (more recently disturbed). *Andropogon* spp., *Dichanthelium* spp., and *Aristida* spp. have all been found to be more abundant soon after a disturbance, followed by a slow decrease in frequency and abundance over time. S*chizachyrium scoparium* and *Andropogon ternarius* were associated with 30- to 80-yr sites. *Schizachyrium scoparium* is considered a late successional plant throughout its range. While *S. scoparium* and *A. ternarius* occurred in all age classes, both increased with recovery time and had higher frequency and cover values on the oldest sites.
Indicators related to vegetation community composition in moderately or less impacted sites are often confounded by residual effects of prior soil disturbance related to agricultural land uses. Plant species potentially sensitive to low to moderate levels of disturbance probably have been extirpated from the sites due to historic levels of chronic disturbances. Indicator species to assess ecological condition may require an evaluation of “natural” or reference conditions prior to their use.

Hydrology

Hydrologic indicators are of significant value for analysis of disturbance or recovery on a watershed scale.

Correlation and regression analyses were performed to determine relationships among the watershed physical characteristics and the storm-based hydrologic indices.
A number of significant relationships were found. The correlation results show that the increase in road density increased the variability in the peak discharges and the slopes of the rising limb. The increase in the military land increased the time of rise as well as the variability in the time base. The number of roads crossing streams is positively correlated with the response lag, whereas it is negatively correlated with the time base and the variability in the slopes of the falling limb. Increase in the bare land and the disturbance index increased the time of rise as well as the variability in the time base. Stepwise multiple correlations identified the relationships between the event indices and the management-related watershed physical characteristics that are susceptible to the disturbances. Military land, road density, and the number of roads crossing streams predicted storm-based baseflow index, bankfull discharge, response lag, and time of rise as well.

Analysis of hydrographs clearly reflects hydrologic imbalances resulting from soil and vegetation disturbance in uplands.
In support of the finding that uplands in non-impacted areas do not contribute to the stream hydrograph, the contributing areas calculated by the stream hydrograph volumes and depth of rainfall events is less than the riparian/wetland area, suggesting that no area outside of the wetland/-riparian area contribute to the stream hydrographs. In training areas, the Ksat is sufficiently low that overland flow could occur. Time of concentration for a 10-cm/hr storm event was about 10 minutes. It is apparent that overland flow has gouged out deep gullies and transported sediment from the hilltops. The flow processes in these areas are observed to be different than those in less-impacted watersheds. Overland flow is conceived to usher water toward roads that channel the water directly to streams, thus by-passing or short-circuiting the natural watershed flow paths.

Soil physical parameters (bulk density, porosity, texture, grain-size distribution, and saturated hydraulic conductivity) are potentially useful at small spatial scale.
Smaller scaling factors imply smaller mean pore sizes of the training soils compared to the non-training soils. The higher soil bulk density values and lower infiltration rates of the training versus non-training areas are indications of the loss of organic matter combined with compaction from repeated tank tracks. The mean steady-state infiltration rate of the training sites (12.0-cm/hr) is less than half that of the non-training sites (26.8-cm/hr), but it is still greater than the maximum 100-yr, 24-hr rainfall intensity of 10 cm/hr.

Stream Water Quality

Stream TOC and TKN concentration decreased with increasing soil and vegetation disturbance (proportion of bare ground) in the watershed, reflecting depletion of soil organic matter and detritus in uplands and reduced leaching in soils due to short-circuited flow paths (gulleys) from uplands to streams.
Watersheds with more roads, e.g., Randall and Oswichee, have relatively high pH, conductivity, and Cl compared to the watersheds with fewer roads. Watersheds with a small portion of military land, e.g., Bonham-1, Sally, and Little Pine Knot, have relatively high TOC concentrations. In contrast, watersheds characterized by higher road densities, e.g., Bonham and Bonham-2, had low TP concentrations. Higher disturbance index, similar to the road density, showed lower TKN and TOC concentrations in the streams. Mixed vegetation, road length, percent of bare land, DIN, and number of roads crossing streams were able to capture most of the variability in water quality parameters.

Enzyme activities relative to patterns of biogeochemistry and soil water content in riparian wetlands varied with distance from stream edge and help explain temporal patterns of groundwater Total Kjeldahl Nitrogen (TKN) related to leaf fall and canopy loss in riparian forests.
Riparian soils were sampled at approximately 80-meter intervals along two streams and in three transects normal to stream flow. Stream and groundwater water chemistry were monitored monthly in transects normal to stream flow in one second order watershed. Variability in microbial enzyme activities and soil total nitrogen (TN) were most closely associated to soil water content, while groundwater Total Kjeldahl Nitrogen (TKN) showed temporal patterns related to leaf fall and canopy loss in riparian

forests and varied with distance from stream edge. Patterns of peptidase activity were complex, with minima observed at approximately 30 percent soil moisture content.

Modeling and Synthesis

Multivariate statistical analyses were applied to 20 biogeochemical parameters in order to discriminate samples based on landscape position, vegetation type, watershed of origin, and disturbance class.
Principal components analysis identified that the total organic matter present in the soil samples (measured as total carbon, total nitrogen, and total phosphorous) was the dominant contributor of variability between the soil samples. Canonical Discriminant Analysis showed that canonical variables could be successfully used to discriminate samples based on landscape position, vegetation type, watershed of origin, and disturbance class. Logistic regression was used to predict the probability of a specific site being disturbed or non-disturbed based on the observed categorical variables and measured biogeochemical variables that were found to effect disturbance.

Near Infrared Reflectance Spectroscopy (NIRS) for soil analysis is rapid, low-cost technique for determination of several individual soil biogeochemical properties and direct evaluation of derived soil quality metrics or indices.
Reflectance measurements and 20 soil biogeochemical variables measured on over 550 soil samples were used to develop a robust Partial Least Square model for independently predicting TC, TN, and TP of new observations based on the reflectance measurements. The results presented indicate that near-infrared spectroscopy coupled with partial least squares can be a useful and inexpensive alternative to expensive and time consuming lab analyses.

General Conclusions

1. Approximately 2 to 15 percent of throughfall shows up as stream flow; median value is approximately 6 percent. Time to peak discharge is approximately 3 hours.
2. Storm intensities are usually <Ksat at most places, except severely disturbed areas.
3. Soil cover plays an important role in determining the potential runoff and may be more important than Ksat of surface soil.

4. Biogeochemical cycling in soils and vegetation are influenced by soil-water content.
5. Soil organic matter and several biogeochemical properties associated with C cycling are important biogeochemical indicators.
6. Spectral analysis shows excellent promise to determine soil nutrient status.
7. Understory vegetation species composition correlates with disturbance. Clear indicators generally observed only at heavily impacted sites.
8. Nutrient and sediment loads in “low” and “medium” impact sites are not too large. Sediment may be the most important water quality attribute for “severe” impact sites.
9. Water quality measurements revealed low levels of most nutrients.
10. Decreased canopy cover in wetlands and hardwood communities of impacted areas increase the nutrient load to streams.
11. Riparian zones play an important role in determining water quality.
12. Multivariate Analysis, Principal Component Analysis, and Canonical Correspondence Analysis yielded combinations of factors that are useful in identifying impacts.

5 Final Report: Development of Ecological Indicator Guilds for Land Management: CS 1114B

SERDP Ecosystem Management Project CS 1114B Executive Summary
Principal Investigator: Dr. Anthony Krzysik
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Introduction

This research is a SERDP-SEMP funded project “Development of Ecological Indicator Guilds for Land Management” (CS 1114B). Agency land-use must be efficiently and cost-effectively monitored to assess conditions and trends in ecosystem processes and natural resources relevant to mission requirements and legal mandates. Ecological Indicators represent important land management tools for tracking ecological changes and preventing irreversible environmental damage in disturbed landscapes. The overall objective of the research was to develop both individual and integrated sets (i.e., statistically derived guilds) of Ecological Indicators to: quantify habitat conditions and trends, track and monitor ecological changes, provide early-warning or threshold detection, and provide guidance for land managers. The derivation of Ecological Indicators was based on statistical criteria, ecosystem relevance, reliability and robustness, economy and ease of use for land managers, multi-scale performance, and stress-response criteria. The basis for the development of statistically based Ecological Indicators was the identification of ecosystem metrics that analytically tracked a landscape disturbance gradient.

Research was conducted in the Fall-Line Sandhills at Fort Benning Georgia. This area represents the complex physiographic ecotone between the Piedmont and Coastal Plain. In Phase I research, nine sites were selected in adjacent watersheds of upland mixed pine-hardwoods forest with loamy-sand soils; three sites each in High, Medium, and Low disturbance classes, based on current and past U.S. Army mechanized infantry training activities. High sites were currently experiencing active mechanized infantry training. Medium sites were subjected to past military training activities, but current use was primarily by foot infantry, and vehicles were restricted to existing roads and trails. Low sites had neither current nor previous military activities and were exposed to minimal foot traffic.

This research has made important scientific advancements in five areas: 1) the identification of individual and classes (guilds) of Ecological Indicators (EIs) that quantify and characterize landscape disturbance; 2) the use of this information to construct Site Comparison or Site Condition Indices (SCIs); 3) new insights into the relationships among landscape disturbance, biodiversity patterns, ecosystem processes, and the intermediate disturbance hypothesis; 4) detailed identification of species-habitat/-environment and landscape disturbance relationships; and 5) the clarification of complex ecosystem and physiological processes. This report essentially deals with the first two, because these were the primary objectives of the proposed research. Numbers three and four are currently being investigated with statistical modeling, especially examining the relationships between biodiversity patterns and landscape disturbance. These analyses are directed primarily at understory (ground cover) and canopy (trees) vegetation and selected invertebrates, especially ant communities. Number five is directly addressed by several publications produced by our team; additional analyses are continuing.

Eleven Ecological Indicator Systems based on extensive research team experience and literature reviews were selected for evaluation in Phase I with respect to a priori selected desirable properties of EIs. These EI systems represented a very broad range of potential physical, chemical, physiological, community, and ecosystem indicators. Eight of the eleven researched EI systems as a group were very effective at distinguishing among the three disturbance classes (High, Medium, Low). These successful EI systems were: General Habitat, General Ground Cover, Floristics Ground Cover, Soil Chemistry, Microbial Community Dynamics, Nutrient Leakage, Soil Mineralization Potential, and Ground/Litter Ant Communities. Developmental Instability (DI), Plant Physiology, and Spatial Organization in Plant Communities were unable to reliably distinguish among disturbance classes. DI is the phenotypic asymmetry response to stress in the early embryonic development of an organism. DI was overly sensitive to a wide range of environmental perturbations, including drought, fire (and nutrient pulses), herbivory, and gall parasitism. Additionally, DI poses significant problems in selection of test species, field sampling, statistical interpretation, and resource-intensive laboratory requirements.

Individual EIs and EI guilds were identified and derived with a number of statistical procedures. Multivariate (MANOVA) and univariate (ANOVA) analysis of variance and discriminant analysis (DA) were used to identify indicator metrics and extract suites of variables (guilds) that successfully discriminated among the disturbance classes. Principal components analysis was useful for reducing field or laboratory data sets (e.g., community species composition, DI metrics) with many variables with high multicollinearity into fewer uncorrelated variables (i.e., vectors) for input into subsequent analyses.

All eight successful EI guilds in Phase I, differing widely in tracking ecosystem condition and responses, demonstrated that the Low and Medium disturbance classes were similar to each other, but differed a great deal from the highly disturbed sites. This indicates that the Medium sites may be well on their recovery trajectory from past military training activities. Nevertheless, Low and Medium sites were also successfully differentiated by all eight EI guilds. DA results from these guilds were reliable, consistent, and robust. Therefore, DA consistently provided a quantitative assessment of the relative ecological differences among the three disturbance classes (i.e., the relative locations of the three disturbance classes in discriminant space).

Soil A-horizon depth and soil compaction were the only EI metrics among all habitat parameters that successfully and significantly ($P<0.001$) distinguished among the three disturbance classes of Phase I. Indeed, these two EIs and soil mineralization potential (consists of two metrics) were the only metrics that individually could distinguish the three disturbance classes. These identified metrics have profound assessment and monitoring implications. Soil is considered the major template for maintaining ecological processes and landscape sustainability. The A-horizon forms at the soil surface by accumulation of humus, and is the layer of highest biodiversity, biological activity, decomposition, and nutrient recycling. Soil compaction has many negative impacts on ecosystem processes including: reduced seed germination and root growth, retarded aeration and water infiltration, increased runoff and erosion, decreased microbial activity and nutrient dynamics, increased difficulty in invertebrate and vertebrate burrowing activities, and discouraging the development of biologically active surface crusts and litter mixing.

It was indeed encouraging to learn that EIs that reflected and mirrored complex ecosystem properties and their dynamics, and community structure and composition were relatively simple; and could economically be monitored by land managers. Research is continuing with the emphasis on multivariate modeling to further weave the tapestry for understanding these complex relationships and interdependencies.

Six of the EI systems successful in Phase I research were validated in a much broader landscape context in Phase II. Soil Mineralization Potential and Nutrient Leakage were not evaluated, because they require a great deal of effort, time, laboratory analyses, and specialized equipment and expertise for monitoring; and are not readily applicable for large sample validation experiments such as our Phase II. However, these Ecological Indicators would be very useful for long-term monitoring of specific fixed sites. Forty sites (including the original 9) were selected throughout Fort Benning, representing relatively pristine to severely degraded military training areas in all available upland vegetation communities and forest types. Site selection was based on 8 GIS databases, site criteria and data from other SEMP research teams, and extensive field ground-truthing. The 40 sites were classified into 10 landscape disturbance classes, based on pre-data collection visual assessment of military training damage to vegetation and soils by a single experienced field ecologist (AJK). A-horizon depth, soil compaction, and DF1 (discriminant function 1) of general ground cover characteristics (dominated by bare ground) when plotted on the 10-class disturbance gradient clearly verifying the utility of these EIs. These three EI metrics were much better at characterizing this disturbance gradient than the more traditionally used NDVI (normalized difference vegetation index) derived from satellite imagery.

A Site Comparison (or Condition) Index (SCI) was constructed from 7 EI metrics: A-horizon depth, soil compaction, soil organic content (correlates with carbon), litter cover (100-bare ground), canopy cover, basal area, tree density; and the NDVI. These eight variables were statistically selected by the criteria that each metric individually varied highly significantly ($P<0.001$) along the 10-class disturbance gradient. Furthermore, the 7 indicator metrics could be measured in the field by minimally trained field personnel using simple and inexpensive equipment. Statistically, NDVI did not contribute any additional information to the SCI. The EI metrics and NDVI were standardized and weighed by statistical procedures. SCI scores for the 40 sites were plotted against the 10 disturbance classes. The

SCI modeled the disturbance gradient monotonically and smoothly. The unbiased analytically derived SCI scores reproduced almost perfectly the ranking assigned by a very experienced observer, thus non-subjective uniformity of ranking was achieved. The histogram of SCI scores for the SCI-ranked 40 sites revealed a sigmoid logistic decay function, analytically demonstrating that relatively few sites were either very high quality or very severely degraded, and suggested a “threshold effect” of rapid decline in SCI values as disturbance increased from “pristine sites” or as severely degraded sites were approached. Discrepancies between SCI and disturbance class rankings revealed interesting ecosystem patterns that are being investigated.

An SCI was similarly calculated for each of the 160 transects at the 40 sites using the 7 EI metrics. Each metric was standardized and weighed by statistical criteria to develop the final composite SCI for the 160 individual transects. A histogram of SCI scores versus the SCI ranked transects again displayed a sigmoid logistic decay curve. The continuity of the curve demonstrated that the complete upland disturbance gradient was characterized at Fort Benning. Based on their ranked SCIs, the 160 transects were classified into five disturbance classes: Low, Low-Med, Medium, Med-High, and High. These five disturbance classes represent an analytically derived and unbiased classification with which to assess the behavior of the other four EI systems: General Ground Cover, Floristics Ground Cover, Microbial Community Dynamics, and the Ground/Litter Ant Community.

Discriminant analyses were conducted on each of these EI systems, and discriminant function (DF) scores were plotted for the five new disturbance classes to assess the response of each EI system along the disturbance gradient. The DFs are vectors that represent weighed linear combinations of the original variables (e.g., indicator metrics). DF1 is the optimal combination of the original metrics that best distinguished the five disturbance classes, and we call this vector a “guild,” because it represents a functional group capable of quantifying and characterizing landscape disturbance. DF1 for both the General and Floristics Ground Cover guild reliably portrayed the disturbance gradient, while for the Ant Community it distinguished between lower and higher disturbance classes. DF2 in all three cases represented a pattern that verified the intermediate disturbance hypothesis. This hypothesis predicts that species richness is highest in sites that are subjected to moderate disturbance, as contrasted to lack of disturbance or severe disturbance. The intermediate disturbance hypothesis has important implications for ecological theory, biodiversity conservation, habitat restoration, and land management. DFs 3 and 4 assisted in the separation of disturbance classes that may have been closely associated in lower order discriminant space. The Microbial Dynamics guild was not included in this report, because errors were detected in its database; these are currently being resolved. Additional analyses and statistical modeling are continuing, particularly in the association of multiple guilds, the relationships of landscape disturbance and biodiversity patterns, and species-habitat modeling.

Our research results in identifying Ecological Indicators and classifying their metrics into guilds in a wide variety of upland vegetation communities in the complex physiographic ecotone and disturbance regimes at Fort Benning are indeed encouraging. Nevertheless, the data were collected at a single location in the Fall-Line Sandhills. Additional data is required from a larger geographic area and an even greater variety of vegetation communities and soil types (especially clayey), both in the Southeast and in other regions of the United States.

Discussion, Conclusions, and Major Points

This research has made important scientific and land management advancements in five areas:

1. The identification of individual and classes (guilds) of Ecological Indicators (EIs) that quantify and characterize landscape disturbance;
2. The use of this information to construct Site Comparison or Site Condition Indices (SCIs);
3. New insights into the relationships among landscape disturbance, biodiversity patterns, ecosystem processes, and the intermediate disturbance hypothesis;
4. Detailed identification of species-habitat/environment and landscape disturbance relationships; and
5. The clarification of complex ecosystem and physiological processes.

This report essentially deals with the first two, because these were the primary objectives of the proposed research. Numbers three and four are currently being investigated with statistical modeling, especially examining the relationships between biodiversity patterns and landscape disturbance. These analyses are directed primarily at understory (ground cover) and canopy (trees) vegetation and selected invertebrates, especially ant communities. Number five is directly addressed by several publications produced by our team, and additional analyses are continuing.

The use of multivariate (MANOVA) and univariate (ANOVA) analyses of variance in conjunction with discriminant analysis (DA) proved to be a powerful approach for the identification and association of EIs in this research. DA extracts discriminant functions (DFs) that are weighed linear combinations of the original predictor variables (e.g., indicator metrics), and therefore, identifies and quantifies the relative importance of these metrics in separating pre-established groups or classes, in this case disturbance classes. Recall, that DA "does not know" any ranking or ordinal nature of the groups. DA "only knows" that there are N-groups that need to be distinguished by a variable set common to all groups. DF1 possesses the greatest discriminating power in separating the groups. DF2 has the next highest power and is orthogonal (independent and uncorrelated) to DF1, and so forth with the remaining DFs. If DF scores of sites or sample transects are ranked correctly in a disturbance gradient (i.e., Low to High disturbance classes), then the variables and their weighing coefficients are an analytical representation of the disturbance gradient. If DF1 accomplishes this, it can be interpreted that the primary separation of the groups is due to disturbance and we have identified the metrics and their relative importance. For example, in Phase I with three disturbance classes, DF1 for the following variable sets was able to accomplish this: General Habitat, Trees (canopy vegetation), General Ground Cover, and Floristic Ground Cover. Other Ecological Indicator Systems were also able to do this. A group of statistically derived variables, weighted or unweighted, that characterized disturbance classes or a disturbance gradient, was called an Ecological Indicator Guild.

Eight of the 11 researched Ecological Indicator Systems in Phase I research were very successful at discriminating among three disturbance classes (High, Medium, Low) using DA. These eight guilds were: General Habitat Metrics, General Ground Cover, Ground Cover Floristics, Soil Chemistry, Nutrient Leakage, Soil Mineralization Potential, Microbial Community Dynamics, and Ground/Litter Ant Communities. Plant Physiology and Spatial Organization in Plant Communities were unable to measure effects due to habitat disturbance. Developmental Instability (DI) of selected plant species was also unable to reliably and consistently distinguish among disturbance classes. DI is the phenotypic asymmetry response to stress in the early embryonic development of an organism. DI was overly sensitive to a wide range of environmental perturbations, including drought, fire (and nutrient pulses), herbivory, and gall parasitism. An inherent problem of DI is that the test species must be present in the entire disturbance gradient. Therefore, the species must possess unusually broad life history characteristics, physiological tolerances, or genetic polymorphism. Additionally, DI analyses require a large number of statistical contrasts and a posteriori comparisons, raising statistical validity issues in sampling and interpretation. An important consideration is that the test species may be selecting similar micro-habitats along the entire disturbance gradient. Military training disturbance is patchy and produces fragmented landscapes, which nevertheless possess higher quality microhabitats, even in heavily used training ranges. On the other hand, microhabitat disturbance patches occur in relatively pristine areas because of disturbance by feral hogs, tree-fall gaps, and the effects from locally severe prescribed burns. The clarification of these problems and issues would require the simultaneous use of laboratory and field transplant experiments, an expensive and resource intensive procedure.

The eight successful EI guilds encompass a very broad range of ecological attributes and ecosystem processes, including: physical and chemical properties of soils; simple, economically obtained properties of vegetation, understory, and canopy floristics; biodiversity metrics; microbial dynamics assessed by how bacteria and fungi partition substrate utilization; nutrient dynamics and leakage; and the structure (species composition and relative abundance) of an ecologically important animal community – ants. A critical feature of these eight EI guilds was their robustness to persistent and major background disturbance perturbations at Fort Benning: weather (e.g., severe drought), prescribed burns, and soil disruption by feral hogs. These covariates were purposely not included in the extraction of EI guilds to assess if their confounding effects were overridden by the underlying disturbance gradient.

All eight successful EI guilds in Phase I, differing widely in tracking ecosystem condition and responses, demonstrated that the Low and Medium disturbance classes were similar to each other, but differed a great deal from the highly disturbed sites. This indicates that the Medium sites may be well on their recovery trajectory from past military training activities. Nevertheless, Low and Medium sites were also successfully differentiated by all eight EI guilds. DA results from these guilds were consistent. Therefore, DA consistently provided a quantitative assessment of the relative ecological differences among the three disturbance classes (i.e., the relative locations of the three disturbance classes in discriminant space).

A-horizon depth and soil compaction were the only EI metrics among all habitat parameters that successfully and significantly ($P<0.001$) distinguished among the three disturbance classes of Phase I. Indeed, these two EIs and soil mineralization potential (consists of two metrics) were the only metrics that individually could distinguish the three disturbance classes. These identified metrics have profound assessment and monitoring implications. Soil is considered the major template for maintaining ecological processes and landscape sustainability.[1] The A-horizon forms at the soil surface by accumulation of humus, and is the layer of highest biological activity, decomposition, and nutrient recycling.[2] Two-thirds of the earth's entire biodiversity live in terrestrial soils and underwater sediments.[3] Soil compaction has many negative impacts on ecosystem processes including: reduced seed germination and root growth, retarded aeration and water infiltration, increased runoff and erosion, decreased microbial activity and nutrient dynamics, increased difficulty in invertebrate and vertebrate burrowing activities, and discouraging the development of biologically active surface crusts and litter mixing.

The Ground Cover Floristic guild consisted of 24 species (plus an unknown morpho-species forb) of ground cover plants extracted from 67 taxa. Ground cover includes shrubs and tree seedlings <2 m in height. These species were: 11 forbs, 7 tree seedlings, 5 shrubs, a woody vine (poison ivy), and brackenfern. All of these species are abundant and widespread in the Southeast. Therefore, their ability to successfully identify the disturbance gradient and separate the disturbance classes on DF1 makes this an important EI guild.

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1 Dylis, N.V. 1968. Principles of construction of a classification of forest biogeocoenoses. Pages 572-589 in Fundamentals of Forest Biogeocoenology, V.N. Sukachev and N.V. Dylis, editors. Oliver and Boyd, London. 672pp; Herrick, J.E. 2000. Soil quality: an indicator of sustainable land management. Applied Soil Ecology 15:75-83; Schoenholtz, S.H., H. Van Miegroet, and J.A. Burger. 2000. A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. Forest Ecology and Management 138:335-356; Johnston, J.M., and D.A. Crossley, Jr. 2002. Forest ecosystem recovery in the southeast US: soil ecology as an essential component of ecosystem management. Forest Ecology and Management 155:187-203; Coleman, D.C., D.A. Crossley, Jr., and P.F. Hendrix. 2004. Fundamentals of Soil Ecology, 2nd ed. Elsevier, New York, NY. 386pp.

2 Perry, D.A. 1994. Forest Ecosystems. Johns Hopkins University Press, Baltimore, MD. 649pp; Ellis, S., and A. Mellor. 1995. Soils and Environment. Routledge, New York, NY. 364pp.

3 Baskin, Y. 2005. Underground: How Creatures of Mud and Dirt Shape Our World. Island Press, Washington, D.C. 237pp.

The Microbial Community Dynamics guild, although successful in separating the disturbance classes, was a significant challenge for statistical inference and interpretation. Because both bacteria and fungi respond to and closely track moisture, temperature, and seasonal availability of litter, detritus, and nutrients; assessing habitat disturbance within this environmentally noisy background will remain a sampling and analysis challenge. Nevertheless, the pattern obtained in the matrix of Table 5-1 was very encouraging. There are 112 cells in this 14 x 8 matrix, but only 18 cells are populated. This directly indicates that seven substrate guilds (derived from an original 95), and the way they are utilized (i.e., total activity or functional richness) independently by bacteria and by fungi to characterize the disturbance gradient are rather specific, and different in uplands versus lowlands.

Table 5-1.. Association of bacteria and fungi primary Microbial Variables (Substrate Guilds and Responses) with discriminant functions (DF) 1 and 2 for upland and lowland habitats. These primary Microbial Variables were common to both data sets: Bonham Creek (6 sites, 2000-2001-2002) and Bonham Creek and Sally Branch (9 sites, 2002).

Microbial Variable	BACTERIA				FUNGI			
Substrate Guild and *Response	Upland		Lowland		Upland		Lowland	
	DF1	DF2	DF1	DF2	DF1	DF2	DF1	DF2
Simple Carbohydrates A					X			
Simple Carbohydrates R	X		X					
Complex Carbohydrates A					X		X	
Complex Carbohydrates R				X		X		
Amines/Amides A				X				
Amines/Amides R			X					
Amino Acids A					X			
Amino Acids R	X							X
Carboxylic Acids A	X							
Carboxylic Acids R	X							
Polymers A							X	
Polymers R							X	
Nucleotides A		X						
Nucleotides R						X		

The Soil Chemistry guild needs to be closely analyzed and integrated with the Microbial guild. Soil Organic Content showed promise in Phase I as an important indicator of habitat disturbance. Analysis demonstrated that nitrate has low concentrations at Low disturbance sites, presumably because of more rapid nutrient uptake by more abundant vegetation or stronger and more stable links to mycorrhizal associations. Higher soil organic matter and lower pH was associated with less disturbed sites. The lower pH is due to the presence of humic acids resulting from more active decomposition processes. It was surprising that microbial biomass carbon did not differ among disturbance classes. This may be a terrestrial example of the "paradox of the plankton" where marine or limnetic biomass trophic pyramids are reversed because of the higher turn-over rates (i.e., energy transfers) of phytoplankton compared to zooplankton. If this is indeed the case, the disturbance classes differ in microbial activity rates (as demonstrated in the microbial guild), while maintaining approximately the same biomass, a most interesting observation.

The Nutrient Leakage guild was subjected to unequal sample sizes among years, sites, seasons, and habitats (uplands and lowlands), because of drought conditions and physical damage to lysimeters by prescribed burns and wildlife, especially feral hogs. Lowland sites exhibited more consistent and greater ion concentrations than upland sites. Moderately disturbance lowland sites retained ions (sodium, potassium, magnesium, and sulfate) better than either less or higher disturbed sites. Highly disturbed upland sites leached more nitrate than less disturbed sites.

The Soil Mineralization Potential guild was very successful at assessing relative habitat disturbance, and shows promise as an indicator for assessing and monitoring forest ecological condition.

Ant communities are gaining interest as biological indicators of disturbance and ecological conditions.[4] The Ground/Litter Ant Community guild with 28 species (103,203 individuals) was very successful at discriminating among the three disturbance classes. *Dorymyrmex smithi* comprised 87 percent of all individuals. This species requires warm nests

[4] Agosti, D., J.D. Majer, L.E. Alonso, and T.R. Schultz, editors. 2000. Ants: Standard Methods for Measuring and Monitoring Biodiversity. Smithsonian Institution Press, Washington D.C. 280pp; Andersen, A.N., and J.D. Majer. 2004. Ants show the way Down Under: invertebrates as bioindicators in land management. Frontiers in Ecology and the Environment 2:291-298; Andersen, A.N., B.D. Hoffmann, W.J. Müller, and A.D. Griffiths. 2002. Using ants as bioindicators in land management: simplifying assessment of ant community responses. Journal of Applied Ecology 39:8-17.

and prefers habitats with open canopy and bare soils, and therefore, dominated the highest disturbed sites and the discriminant analysis. Nevertheless, the removal of the species for subsequent analyses had no effect on analysis results, indicating the robustness of the ant community as an effective and reliable EI guild. Five species of ants (554 individuals) were particularly successful at discriminating the disturbance gradient: *Aphaenogaster floridana*, *Camponotus castaneus*, *Letptothorax texana*, *Paratrechina parvula*, and *Solenopsis molesta* (native fire ant). The abundant imported fire ant (*Solenopsis invicta*) was present in the 28-species analysis, but did not contribute significantly to disturbance class discrimination.[5]

It is important to recall that the Fort Benning landscape has been subjected to a wide variety of landscape disturbances: historical agricultural activities (including associated infrastructure), historical major and recent managed timber harvest, recent mechanized U.S. Army mechanized infantry training, and frequent prescribed burns. Historical environmental disturbances although quantitatively unaccountable, undoubtedly significantly alter, often appreciably, current ecosystem structure, dynamics, and processes. Present day plant community species composition and species richness in northeastern France are the direct result of agricultural intensity during the period AD 50-250.[6] Therefore, soil degradation from past land-use may be irreversible on historical time scales. Current field measures of ecosystem condition and properties and their reference to disturbance represent the cumulative reflection of all the historical and current anthropogenic and natural disturbance regimes subjected to the landscape with no hope of unraveling all the details. Nevertheless, the careful selection of relatively pristine reference sites statistically contrasted to a broad landscape disturbance gradient has identified important Ecological Indicators of habitat disturbance, with the opportunity to analytically associate indicator metrics with ecosystem structure, function, and processes; and therefore, providing important monitoring capabilities for land managers.

The individual EI metrics identified in Phase I research were validated in a much broader landscape context in Phase II. Forty sites (including the

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[5] Graham, J.H., H.H. Hughie, S. Jones, K. Wrinn, A.J. Krzysik, J.J. Duda, D.C. Freeman, J.M. Emlen, J.C. Zak, D.A. Kovacic, C. Chamberlin-Graham, and H.E. Balbach. 2004. Habitat disturbance and the diversity and abundance of ants (Formicidae) in the Southeastern Fall-Line Sandhills. Journal of Insect Science 4:30, 15pp. (online at http://insectscience.org/4.30/)

[6] Dupouey, J.L., E. Dambrine, J.D. Laffite, and C. Moares. 2002. Irreversible impact of past land use on forest soils and biodiversity. Ecology 83:2978-2984.

original nine from Phase I) were selected throughout Fort Benning representing relatively pristine to severely degraded military training areas in all available upland plant communities and forest types. These sites were classified into 10 disturbance classes before field data were collected, based on a visual assessment of disturbance to vegetation and soils. A-horizon depth, soil compaction, and DF1 of general ground cover characteristics (dominated by bare ground) were plotted on the 10-class disturbance gradient; clearly verifying the utility of these EIs. These three EI metrics were far more effective at characterizing this disturbance gradient than the more traditionally used NDVI (normalized difference vegetation index) derived from satellite imagery.

A Site Comparison (or Condition) Index was constructed from seven EI metrics: A-horizon depth, soil compaction, soil organic content (correlates with carbon), litter cover (100-bare ground), canopy cover, basal area, tree density; and the NDVI. Statistically, the NDVI did not contribute any additional information to the SCI. Weighing coefficients were developed for the EI metrics and NDVI based on statistical procedures. SCI scores for the 40 sites were plotted against the 10 disturbance classes. The SCI modeled the disturbance gradient monotonically and smoothly. The unbiased analytically derived SCI scores reproduced almost perfectly the ranking assigned by a very experienced observer, thus non-subjective uniformity of ranking was achieved.

The histogram of SCI scores for the SCI ranked 40 sites revealed a sigmoid logistic decay function, analytically demonstrating that relatively few sites were either very high quality or very severely degraded, and suggested a “threshold effect” of rapid decline in SCI values as disturbance increased from “pristine sites” or as severely degraded sites were approached. Discrepancies between SCI and Disturbance Class (DC) rankings revealed interesting ecosystem patterns. Deciduous forests with their high canopy cover and tree biomass and complex vegetation layers scored the highest with both the SCI and DC ranking. On the other hand, a pristine xeric scrub oak–longleaf pine savanna (DC1) with relatively open canopy and less complex vegetation was ranked ninth with the SCI. The lowest SCI ranked site was in the center of the Delta Training Ranges, and was highly degraded possessing a great deal of bare ground. A relatively pristine longleaf pine forest in rocky rolling hills with very simple vegetation structure was ranked 19th (in the middle of the SCI gradient), but was in DC2. This site is one of Fort Benning's protected Unique Ecological Areas - Arkansas Oak Rock Hills.

The use of indices to classify or characterize landscape parcels raises an interesting caveat. This is exactly analogous to the calculation of a diversity index, a frequently used index for environmental monitoring and environmental impact assessment. The diversity index consists of two metrics: species richness (i.e., number of species) and evenness (the relative abundances among individual species). Even though there is a high positive correlation between the index and species richness with the accumulation of many samples, one can never be sure which of the two components of the index is more important when comparing any two specific samples. Two samples with the identical species diversity index may, nevertheless, differ dramatically in community structure. One community may possess a very large number of species with highly skewed species-abundance patterns. In other words, there are a few dominants, but most species are very rare. The other community may have relatively few species, but each species possesses similar abundances. These are compositionally, and undoubtedly functionally as well, dramatically different communities, but are described as identical by a diversity index. Similarly, and more meaningful to a land manager, high basal area can be achieved by either relatively few giant trees or a high density of very small trees. The basal area metric alone cannot distinguish between these two extreme possibilities.

The SCI has been useful and unbiased in analytically quantifying landscape disturbance, and was instrumental in identifying the relationship between biodiversity elements and habitat disturbance.[7] However, the SCI raises the same ambiguity as the diversity index, especially when trying to compare across different community physiognomies. A-horizon and soil compaction are highly negatively correlated at the 40 sites (Spearman's rho: -0.72, $P<0.001$). However, land managers are often more interested in comparing two specific sites, than knowing summary metrics for a large sample of parcels. Extreme values in either A-horizon or soil compaction can disguise moderate values in both. Historical soil A-horizon losses from agriculture or timber harvest may be associated with low soil compaction, because of minimal disturbance by tactical or other off-road vehicles. Level

[7] Krzysik, A.J., H.E. Balbach, D.A. Kovacic, J.H. Graham, M.P. Wallace, J.J. Duda, J.C. Zak, D.C. Freeman, and J.M. Emlen. 2005a. The relationship between landscape disturbance and biodiversity using ecological indicators and a site comparison index. XVII International Botanical Congress, Vienna, Austria. 17-23 July 2005.

topography not plowed with uneroded soils may have deep A-horizons, but be heavily compacted by recent tactical vehicle maneuvers. The sensitivity of soils to compaction is highly dependent on clay content. The bottom line is that each metric in an index carries unique and important environmental information that is only “averaged” in the construction of an index. Land managers and ecologists must be equally cognizant of the benefits and limitations of indices. The continued refinement of SCIs is encouraged, but they must be used with the concurrent responses of the individual metrics that comprise them.

SCI scores, based on the seven indicator metrics (six General Habitat metrics and a Soil Chemistry metric, NDVI, were not used) were also calculated for the 160 transects at the 40 sites, and the resulting histogram also revealed a sigmoid logistic decay function. The 160 transects were divided into five disturbance classes: Low, Low-Med, Medium, Med-High, High. Discriminant analysis with the interpretation of DF1 demonstrated that General Ground Cover and Floristics Ground Cover indicator guilds clearly characterized the landscape disturbance gradient, even with the use of a wide variety of plant communities. The DA result of the ant communities was not as direct on the disturbance gradient. Ant community structure on DF1, as characterized by species composition and relative abundance, was similar in Low to Medium disturbance classes, and differed at both Med-High and High disturbance. The three Low to Medium disturbance classes were clearly separated by DF3 and DF4. This result indicates that although all five disturbance classes could be separated by DA based on ant community structure, there was no monotonic change in ant community structure based on the disturbance gradient. This may be attributed to the broad variety of plant communities represented in the disturbance gradient. In other words, ant community species composition and relative abundance was not only responding to the disturbance gradient, but also to the nature of the plant community (forest type and succession stage).

We have seen above in the three DAs that DF1 has the most discriminating set of weighed indicator metrics that characterize the overall disturbance gradient. A most interesting, important, and unexpected result is the examination of DF2, the second most important DF for separating the five disturbance classes, and uncorrelated with DF1. Note that all three guilds: General Ground Cover, Floristics Ground Cover, and Ant Communities validate the intermediate disturbance hypothesis, based on our analytical description of a broad landscape disturbance gradient in a diverse assemblage of plant communities. This result is of significant importance to ecological theory, restoration strategies, and land management approaches concerning the organization and succession of ecological communities. Additionally, we have also demonstrated the intermediate disturbance hypothesis directly with species richness and the diversity index of ant communities, and six measures of ground cover: woody, forbs, legumes, Opuntia, Yucca, and total.[8] Species-habitat and landscape disturbance relationships are further being investigated and modeled with NMS (nonmetric multidimensional scaling), CCA (canonical correspondence analysis), SEM (structural equation modeling), neural networks, and several other techniques.

Our research results in identifying Ecological Indicators and classifying their metrics into guilds in a wide variety of upland vegetation communities in the complex physiographic ecotone and disturbance regimes at Fort Benning are indeed encouraging. Nevertheless, the data were collected at a single location in the Fall-Line Sandhills. Additional data are required from a larger geographic area and an even greater variety of vegetation communities and soil types (especially clayey), both in the Southeast and in other regions of the United States if either the principles or the values developed here are to be applied more widely.

[8] Krzysik, A.J., et al. 2005b. Landscape disturbance and biodiversity patterns of vegetation and ants in a complex regional ecotone. Presentation. Joint meeting: Ecological Society of America and International Congress of Ecology, 11 August 2005, Montreal, Quebec, Canada; Graham, J.H., A.J. Krzysik, D.A. Kovacic, J.J. Duda, D.C. Freeman, J.M. Emlen, J.C. Zak, W.R. Long, M.P. Wallace, C. Chamberlin-Graham, J. Nutter, and H.E. Balbach. 2005. Intermediate disturbance and ant communities in a forested ecosystem. Submitted for publication.

6 Final Report: Indicators of Ecological Change: CS1114C

SERDP Ecosystem Management Project CS 1114C Executive Summary
Principal Investigator: Dr. Virginia H. Dale
Oak Ridge National Laboratory

Introduction and Background

Some of the finest surviving natural habitat in the United States is on military reservations where land has been protected from development. However, military training activities often necessitate ecological disturbance to that habitat. Fort Benning, Georgia, contains active infantry training grounds and more than 65,000 ha of soils capable of supporting longleaf pine (*Pinus palustris*) forest, a greatly reduced forest type in the North America. Because longleaf pine forests are the primary habitat for the federally-endangered red-cockaded woodpecker (*Picoides borealis*), land managers at this installation have a dual charge both to maintain conditions for mechanized training activities and to conserve the integrity of this landscape.

Characterizing how resource use and management activities affect ecological conditions is necessary to document and understand ecological changes. Resource managers on military installations have the delicate task of balancing the need to train soldiers effectively with the need to maintain ecological integrity. Ecological indicators can play an important role in the management process by providing feedback on the impacts that training has on environmental characteristics.

The challenge in using ecological indicators is in determining which of the numerous measures of ecological systems best characterize the entire system but are simple enough to be effectively monitored and modeled. Ecological indicators quantify the magnitude of stress, degree of exposure to stress, or degree of ecological response to the exposure and are intended to offer a simple and efficient method to examine ecological composition, structure, and function of whole systems. The use of ecological indicators as a monitoring device relies on the assumption that the presence or absence of, and fluctuations in, these indicators reflect changes taking place at various levels in the ecological hierarchy.

Although few scientists deny the benefits that indicators provide to research and management efforts, three concerns jeopardize the use of ecological indicators as a management tool.

- Management and monitoring programs often depend on a small number of indicators and, as a consequence, fail to consider the full complexity of the ecological system. By selecting only one or a few indicators, the focus of the ecological management program becomes narrow, and an oversimplified understanding of the spatial and temporal interactions is created. This simplification often leads to poorly informed management decisions. Indicators should be selected from multiple levels in the ecological hierarchy in order to effectively monitor the multiple levels of complexity within an ecological system.

- Choice of ecological indicators is often confounded by management programs that have vague management goals and objectives. Unclear or ambivalent goals and objectives can lead to "the wrong variables being measured in the wrong place at the wrong time with poor precision or reliability."[1]

- Primary goals and objectives should be determined early in the process in order to focus management activities. Ecological indicators can then be selected from system characteristics that most closely relate to those management concerns.

- Management and monitoring programs often lack scientific rigor because of their failure to use a defined protocol for identifying ecological indicators. Lack of a procedure for selecting ecological indicators makes it difficult to validate the information provided by those indicators. Until a standard method is established for selecting and using indicators, interpretation of their change remains speculative. The creation and use of a standard procedure for the selection of ecological indicators allow repeatability, avoid bias, and impose discipline upon the selection process, ensuring that the selection of ecological indicators encompasses management concerns.

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[1] Noss, R.F., Cooperrider, A.Y., 1994. Saving Natures Legacy. Island Press, Washington, DC.

Development of a procedure for ecological indicator selection that is based on a hierarchical framework and grounded in clear management goals will address concerns associated with the subjective and disorganized methods often used. We present such an approach for identifying ecological indicators. The ultimate goal is to establish the use of ecological indicators as a means for including ecological objectives and concerns in management decisions.

The approach is applied to Department of Defense (DoD) lands in the United States where military land contributes significantly to habitat conservation. The DoD manages more than 10 million ha representing more than 450 installations nationally. Although this area is much less land than the area managed by the Department of the Interior (180 million ha) or the United States Forest Service (77 million ha), greater species diversity per unit area exists within DoD lands than within lands of any other federal ownership (except Department of Energy lands). In addition, DoD lands contain more endangered species per unit area than any other federal land management agency, and individual installations often contain more contiguous land than most national parks or wildlife refuges. While a portion of all military installations is highly disturbed, most land within military bases is designated as light intensity training areas or buffer zones and, therefore, remains in a relatively natural state, providing numerous habitats and a haven for associated species. These facts coupled with the DoD's commitment to ecosystem management and conservation provide an outstanding opportunity for establishing sustainable management practices that ensure the future of these habitat and species resources. Although its mission is military training and testing, the DoD recognizes the relationship between its military mission and the natural resources upon which that mission depends, and, therefore, the benefits of creating and implementing long-term ecosystem-management plans.[2]

This research explored the use of ecological indicators as a land management tool, focusing on the development of a procedure for selecting and monitoring ecological indicators. In response to the limitations that currently hamper the effectiveness of ecological indicators as a management device, we considered a hierarchical approach to land management and the role indicators can play in providing the monitoring information required by ecosystem management. This summary discusses criteria and

[2] Goodman, Sheri W. March 25, 1994. Environmentally and Economically Beneficial Practices on Federally Landscaped Grounds. Deputy under Secretary of Defense (Environmental Security) Memorandum.

presents the suite of indicators that we considered for military land use at the landscape, watershed and plot level. The development and implementation of land-management strategies for military land not only provide valuable tools for the continued mission of the DoD but also suggest how ecological indicators can be used for ecosystem management of other multiple-use lands.

Criteria for Selecting Ecological Indicators

Selection of effective indicators is key to the overall success of any monitoring program. In general, ecological indicators need to capture the complexities of the ecosystem yet remain simple enough to be easily and routinely monitored. In order to define ecological indicators, however, it is first necessary to set forth criteria used to select potential ecological indicators. Building upon discussions in the scientific literature and discussions with the other SERDP Environmental Management Project (SEMP) research teams and the resource managers at Fort Benning, we suggest that ecological indicators should meet the following criteria:

- *Be easily measured.*
  The indicator should be straightforward and relatively inexpensive to measure. The metric needs to be easy to understand, simple to apply, and provide information to managers and policymakers that is relevant, scientifically sound, easily documented, and cost-effective.
- *Be sensitive to stresses on the system.*
  The ideal ecological indicator is responsive to stresses placed on the system by human actions while also having limited and documented sensitivity to natural variation. While some indicators may respond to all dramatic changes in the system, the most useful indicator is one that displays high sensitivity to a particular and, perhaps, subtle stress, thereby serving as an early indicator of reduced system integrity.
- *Respond to stress in a predictable manner.*
  The indicator response should be unambiguous and predictable even if the indicator responds to the stress by a gradual change. Ideally, there is some threshold response level at which the observable response occurs before the level of concern.
- *Be anticipatory, that is, signify an impending change in key characteristics of the ecological system.*
  Change in the indicator should be measurable before substantial change in ecological system integrity occurs.

- *Predict changes that can be averted by management actions.*
  The value of the indicator depends on its relationship to possible changes in management actions.
- *Are integrative: the full suite of indicators provides a measure of coverage of the key gradients across the ecological systems (e.g., gradients across soils, vegetation types, temperature, space, time, etc.).*
  The full suite of indicators for a site should integrate across key environmental gradients. For example, no single indicator is applicable across all spatial scales of concern. The ability of the suite of indicators to embody the diversity in soils, topography, disturbance regimes, and other environmental gradients at a site should be considered.
- *Have a known response to disturbances, anthropogenic stresses, and changes over time.*
  The indicator should have a well documented reaction to both natural disturbance and to anthropogenic stresses in the system.
- *Have low variability in response.*
  Indicators that have a small range in response to particular stresses allow for changes in the response value to be better distinguished from background variability.

Landscape Indicators

This research examined landscape indicators that signal ecological change in both intensely used and lightly used lands at Fort Benning, Georgia. Changes in patterns of land cover through time affect the ecological system by altering the proportion and distribution of habitats for species that these cover types support. Landscape patterns, therefore, are important indicators of land-use impacts, past and present, upon the landscape. This analysis of landscape pattern began with a landscape characterization based on witness tree data from 1827 and the 1830s and remotely sensed data from 1974, 1983, 1991, and 1999. The data from the early 1800s, although coarse, were useful in characterizing the historical range of variability in ecological conditions for the area. The steps for the analysis involved the creation of a land-cover database and a time series of land cover maps, computation of landscape metrics, and evaluation of changes in those metrics over time as evidenced in the land-cover maps. We focused on five cover types (bare/developed land, deciduous forest, mixed forest, pine forest, and nonforest vegetated land), for they reveal information important to resources management at Fort Benning. An examination of land-cover class and landscape metrics, computed from the maps, indicated that a suite of metrics adequately describes the changing landscape at Fort Benning, Georgia. The most appropriate metrics were percent cover, total edge (km), number of patches, descriptors of patch area, nearest neighbor distance, the mean perimeter-to-area ratio, shape range, and clumpiness. Identification of such ecological indicators is an important component of building an effective environmental monitoring system.

Watershed Indicators

To evaluate watershed scale indicators of disturbance we studied twelve 2nd- and 3rd-order streams in the eastern part of the Fort Benning Military Installation (FBMI) that drained watersheds with a wide range of disturbance levels. We quantified watershed disturbance as the sum of the proportion of bare ground on slopes >3 percent and unpaved road cover within each watershed. Study streams drained watersheds ranging in disturbance from about 2 to 14 percent. We then compared a variety of stream physical, chemical, and biological characteristics across this disturbance gradient to evaluate their usefulness as disturbance indicators.

We found that a number of stream characteristics were good indicators of watershed-scale disturbance at FBMI. Stream channel organic variables (i.e., amount of benthic particulate organic matter [BPOM] and coarse woody debris [CWD]) were highly related to watershed disturbance as was the degree of hydrologic flashiness (quantified by 4-hour storm flow recession constants) and bed stability. Among the stream chemistry variables, the concentrations of total and inorganic suspended sediments during baseflow and storm periods were excellent indicators of disturbance, typically increasing with increasing disturbance levels. In addition, baseflow concentrations of dissolved organic carbon and soluble reactive phosphorus were good disturbance indicators, declining with increasing disturbance levels. Among biological variables, stream benthic macroinvertebrates also were good indicators of watershed-scale disturbance. Traditional measures such as community richness (e.g., number of Ephemeroptera, Plecoptera, and Trichoptera [EPT] taxa and richness of Chironomidae) negatively corresponded with watershed disturbance; however, except for chironomid richness, all measures showed high variation among seasons and annually. A multimetric index previously designed for Georgia streams (Georgia Stream Condition Index [GASCI]) consistently indicated watershed disturbance and also showed low seasonal and inter-annual variation. Low diversity of fish precluded use of traditional measures (i.e., richness, diversity), however the proportional abundance of the two dominant populations (*P. euryzonus* and *S. tho-*

reauianus) were strongly but oppositely associated with disturbance, with *P. euryzonus* and *S. thoreauianus* being negatively and positively related to disturbance, respectively. Finally, historical land use explained more variation in contemporary bed stability and longer-lived, low turnover taxa than contemporary land use, suggesting a "legacy" effect on these stream measures. Prior to identification and use of potential indicators, managers at FBMI should acknowledge historical land use and the possible presence of legacy effects on aquatic physicochemical and biotic contitions.

Plot-level Indicators

Vegetation Indicators

Environmental indicators for longleaf pine (*Pinus palustris*) ecosystems need to include some measure of understory vegetation because of its responsiveness to disturbance and management practices. To examine the characteristics of understory species that distinguish between disturbances induced by military traffic, we randomly established transects in four training intensity categories (reference=no military use, light=foot traffic only, moderate=marginal tracked vehicle use, and heavy=regular tracked vehicle use) and in an area that had been remediated following intense disturbance at Fort Benning, Georgia. A total of 137 plant species occurred in these transects with the highest diversity (95 species) in light training areas and the lowest (16 species) in heavily disturbed plots. Forty-seven species were observed in only one of the five disturbance categories. The variability in understory vegetation cover among disturbance types was trimodal ranging from less than 5 percent cover for heavily disturbed areas to 67 percent cover for reference, light, and remediated areas. High variability in species diversity and lack of distinctiveness of understory cover led us to consider Raunkiaer life form and plant families as indicators of military disturbance. Life form successfully distinguished between plots based on military disturbances. Species that are phanerophytes (trees and shrubs) were the most frequent life form encountered in sites that experienced light infantry training. Therophytes (annuals) were the least common life form in reference and light training areas. Chamaephytes (plants with their buds slightly above ground) were the least frequent life form in or moderate and remediation sites. Heavy training sites supported no chamaephytes or hemicryptophtes (plants with dormant buds at ground level). The heavy, moderate, remediated, and reference sites were all dominated by cryptophytes (plants with underground buds) possibly because of their ability to withstand both military disturbance and ground fires (the natural disturbance of longleaf pine forests). Analysis of soils collected from each transect revealed that depth of the A layer of soil was significantly higher in reference and light training areas, which may explain the life form distributions. In addition, the diversity of plant families and, in particular, the presence of grasses and composites were indicative of training and remediation history. These results are supported by prior analysis of life form distribution subsequent to other disturbances and demonstrate the ability of life form and plant families to distinguish between military disturbances in longleaf pine forests.

We further investigated the hypothesis that effects of military activity on these forests may be quantified by grouping understory species into life-forms by experimentally manipulating a longleaf pine forest using a mechanized vehicle. In May 2003, a D7 bulldozer removed extant vegetation and surface soil organic matter along three treatment transects. Braun-Blanquet vegetation surveys were recorded in June and September 2003 and 2004. Repeated measures analysis of variance was utilized to compare the response of 30 plots within the treatment transects to 30 plots in adjacent control transects. Total understory cover in the treatment transects decreased substantially in June, but rebounded by September 2003. Phanerophytes (trees and shrubs) in the treatment plots maintained reduced cover throughout the growing season. These findings support the use of Raunkiaer functional types in indicating the response of longleaf pine forests to mechanized disturbance. This approach should lead to a readily accessible measure of disturbance that can be assessed throughout the installation by land managers.

Microbial Indicators

This research demonstrated that the soil microbial community of a longleaf pine ecosystem at Fort Benning, Georgia, also responds to military traffic disturbances. Using the soil microbial biomass and community composition as ecological indicators, reproducible changes showed increasing traffic disturbance decreases soil viable biomass, biomarkers for microeukaryotes, and Gram-negative bacteria, while increasing the proportions of aerobic Gram-positive bacterial and actinomycete biomarkers. Soil samples were obtained from four levels of military traffic (reference, light, moderate, and heavy) with an additional set of samples taken from previously damaged areas that were remediated via planting of trees and ground cover. Utilizing 17 phospholipid fatty acid (PLFA) variables that differed significantly with land usage, a linear discriminant analysis with cross-validation classified the four groups. Wilks' Lambda for the model was 0.032 ($P<0.001$). Overall, the correct classification of profiles was 66 percent (compared to the chance that 25 percent would be correctly classified). Using this model, ten observations taken from the remediated transects were classified. One observation was classified as a reference, three as light trafficked, and six as moderately trafficked. Non-linear Artificial Neural Network (ANN) discriminant analysis was performed using the biomass estimates and all of the 61 PLFA variables. The resulting optimal ANN included five hidden nodes and resulted in an r^2 of 0.97. The prediction rate of profiles for this model was again 66 percent, and the ten observations taken from the remediated transects were classified with four as reference (not impacted), two as moderate, and four as heavily trafficked. Although the ANN included more comprehensive data, it classified eight of the ten remediated transects at the usage extremes (reference or heavy traffic). Inspection of the novelty indexes from the prediction outputs showed that the input vectors from the remediated transects were very different from the data used to train the ANN. This difference suggests that as a soil is remediated it does not escalate through states of succession in the same way as it descends following disturbance.

Considering Soil, Vegetation, and Microbial Indicators Together

Our results and those of Chuck Garten[3] (under another SEMP project) show that soil chemistry, soil microbes, and vegetation are all important indicators of ecological change. Accordingly, we questioned whether all of these indicators would be important if we combined these data into one analysis. Our hypothesis was that a suite of indicator types is necessary to explain ecological change. A discriminant function analysis was conducted to determine whether these ecological indicators could differentiate between different levels of military use. A combination of ten indicators explained 90 percent of the variation among plots from five different military-use levels. Results indicated that an appropriate suite of ecological indicators for military resource managers includes vegetation, microbial, and soil characteristics. This result is important for resource managers since many of the indicators are correlated; it implies that managers will have freedom to choose indicators that are relatively easy to measure, without sacrificing information.

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[3] Garten, C.T., T.L. Ashwood, and V.H. Dale. 2003. Effect of military training on indicators of soil quality at Fort Benning, Georgia. Ecological Indicators 3(3) 171-180.

Road and Vehicle Impacts at Different Scales at Fort Benning

Roads and vehicles change the environmental conditions in which they occur. One way to categorize these effects is by the spatial scale of the cause and the impacts. Roads may be viewed from the perspective of road segments, the road network, or roads within land ownership or political boundaries such as counties. Our research examined the hypothesis that the observable impacts of roads on the environment depend on spatial resolution. To examine this hypothesis, the environmental impacts of vehicles and roads were considered at four scales in west central Georgia in and around Fort Benning: a second-order catchment, a third-order watershed, the entire military installation, and the five-county region including Fort Benning. Impacts from an experimental path made by a tracked vehicle were examined in the catchment. Land-cover changes discerned through remote sensing data over the past three decades were considered at the watershed and installation scales. A regional simulation model was used to project changes in land cover for the five-county region. Together these analyses provide a picture of the how environmental impacts of roads and vehicles can occur at different spatial scales. Following tracked vehicle impact with a D7 bulldozer, total vegetation cover responded quickly, but the plant species recovered differently. Soils were compacted in the top 10 cm and are likely to remain so for some time. Examining the watershed from 1974 to 1999 revealed that conversion from forest to nonforest was highest near unpaved roads and trails. At the installation scale, major roads as well as unpaved roads and trails were associated with most of the conversion from forest to nonforest. For the five-county region, most of the conversion from forest to nonforest is projected to be due to urban spread rather than direct road impacts [using a model developed for another SERDP project, RSim, SI-1259]. The study illustrates the value of examining the effects of roads at several scales of resolution and shows that road impacts in west-central Georgia are most important at local to subregional scales.

Technology Transfer

The objective of this study was to identify indicators that signal ecological change in intensely and lightly used ecological systems (all Fort Benning has had some anthropogenic changes) that could be used by the resource managers. Because the intent was that these indicators become a part of the ongoing monitoring system at the installation, the indicators were selected for their feasibility for the installation staff to measure and interpret. While the focus was on Fort Benning, the goal was to develop an approach to identify indicators that would be useful to a diversity of military installations and other land ownerships (in some cases the actual indicators may be adopted). The intent of this identification of indicators was to improve managers' ability to manage activities that are likely to be damaging and to prevent long-term, negative effects. Therefore, we examined a suite of variables needed to measure changes in ecological conditions. The results of our research were presented to the Fort Benning Resource managers in a half day workshop in February 2005.

7 Final Report: Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality: CS 1114D

SERDP Ecosystem Management Project CS 1114D Executive Summary
Principal Investigator: Mr. Charles Garten
Oak Ridge National Laboratory

Introduction

Research was conducted on soil carbon and nitrogen dynamics at Fort Benning, GA, from October 1999 to June 2004. The objectives of the research were to (1) develop a better understanding of the effects of disturbance on key measures of soil quality at Fort Benning, and (2) determine if there are thresholds of soil quality that potentially affect ecosystem recovery or sustainability. The completed research was relevant to SERDP because it addressed several objectives in the Statement of Need No. CSSON-00-03 titled “Ecological Disturbance in the Context of Military Landscapes.” In particular, the research addressed the SON objective “to determine whether there are thresholds in spatial extent, intensity or frequency above and/or below which the natural system cannot sustain identified ecological and/or land use disturbances.”

There were five broadly based technical objectives associated with the research: (1) characterize effect of disturbances and land cover/land use on soil quality, (2) predict disturbance thresholds to ecosystem recovery, (3) model soil organic matter for different land cover types, (4) contribute to and conduct field experiments on ecosystem disturbance, and (5) analyze spatial patterns of soil carbon and nitrogen for the purpose of predicting potential non-point nitrogen sources on the landscape. Data from the research has been submitted to the SEMP Data Repository in multiple data sets and is available via the internet. The principal findings from each technical objective associated with the research are summarized in this final report. For additional details, the reader is referred to the various ORNL technical reports for this project listed in Appendix B.

Technical Objective 1: Characterize Effect of Disturbances and Land Cover/Land Use on Soil Quality

The purpose of this task was to investigate the effects of soil disturbance on several key indicators of soil quality at Fort Benning, Georgia. Military activities at Fort Benning that result in soil disturbance include infantry, artillery, wheeled, and tracked vehicle training. Soil samples were collected along a disturbance gradient that included: (1) reference sites, (2) light military use, (3) moderate military use, (4) heavy military use, and (5) remediated sites. With the exception of surface soil bulk density, measured soil properties at reference and light use sites were similar. Relative to reference sites, greater surface soil bulk density, lower soil carbon concentrations, and less carbon and nitrogen in particulate organic matter (POM) were found at moderate use, heavy use, and remediated sites. Studies along a pine forest chronosequence indicated that carbon stocks in POM gradually increased with stand age. An analysis of soil C:N ratios, as well as soil carbon concentrations and stocks, indicated a recovery of soil quality at moderate military use and remediated sites relative to heavy military use sites. Measurements of soil carbon and nitrogen are ecological indicators that can be used by military land managers to identify changes in soil from training activities and to rank training areas on the basis of soil quality.[1]

Land cover characterization might also help land managers assess the impacts of management practices and land cover change on attributes linked to the maintenance and/or recovery of soil quality. However, connections between land cover and measures of soil quality are not well established. We examined differences in soil carbon and nitrogen among various land cover types at Fort Benning, Georgia. Forty-one sampling sites were classified into five major land cover types: deciduous forest, mixed forest, evergreen forest or plantation, transitional herbaceous vegetation, and barren land.

Key measures of soil quality (including mineral soil density, nitrogen availability, soil carbon and nitrogen stocks, as well as properties and chemistry of the O-horizon) were significantly different among the five land covers. In general, barren land had the poorest soil quality. Barren land, created through disturbance by tracked vehicles and/or erosion, had

[1] Garten, C.T., Jr., T.L. Ashwood, and V.H. Dale. 2003. Effect of military training on indicators of soil quality at Fort Benning, Georgia. Ecological Indicators 3:171-179.

significantly greater soil density and a substantial loss of carbon and nitrogen relative to soils at less disturbed sites. It was estimated that recovery of soil carbon under barren land at Fort Benning to current day levels under transitional vegetation or forests would require about 60 years following reestablishment of vegetation. Maps of soil carbon and nitrogen were produced for Fort Benning based on a 1999 land cover map and field measurements of soil carbon and nitrogen stocks under different land cover categories.[2]

Technical Objective 2: Determine Disturbance Thresholds to Ecosystem Recovery

The objective of this task was to use a simple model of soil carbon and nitrogen dynamics to predict nutrient thresholds to ecosystem recovery on degraded soils at Fort Benning, Georgia. The model calculates aboveground and belowground biomass, soil carbon inputs and dynamics, soil nitrogen stocks and availability, and plant nitrogen requirements. A threshold is crossed when predicted soil nitrogen supplies fall short of predicted nitrogen required to sustain biomass accrual at a specified recovery rate. Four factors were important to development of thresholds to recovery: (1) initial amounts of aboveground biomass, (2) initial soil carbon stocks (i.e., soil quality), (3) relative recovery rates of biomass, and (4) soil sand content. Thresholds to ecosystem recovery predicted by the model should not be interpreted independent of a specified recovery rate. Initial soil carbon stocks influenced the predicted patterns of recovery by both old field and forest ecosystems. Forests and old fields on soils with varying sand content had different predicted thresholds to recovery. Soil carbon stocks at barren sites on Fort Benning generally are below predicted thresholds to 100 percent recovery of desired future ecosystem conditions defined on the basis of aboveground biomass (18000 versus 360 g m-2 for forests and old fields, respectively). Calculations with the model indicated that reestablishment of vegetation on barren sites to a level below the desired future condition is possible at recovery rates used in the model, but the time to 100 percent recovery of desired future conditions, without crossing a nutrient threshold, is prolonged by a reduced rate of forest growth. Predicted thresholds to ecosystem recovery were less on soils with more than 70 percent sand content. The lower thresholds for old field and forest recovery on more sandy soils are apparently due to higher relative

[2] Garten, C.T., Jr., and T.L. Ashwood. 2004a. Land cover differences in soil carbon and nitrogen at Fort Benning, Georgia. ORNL/TM-2004/14. Oak Ridge National Laboratory, Oak Ridge, TN.

rates of net soil nitrogen mineralization in more sandy soils. Calculations with the model indicate that a combination of desired future conditions, initial levels of soil quality (defined by soil carbon stocks), and the rate of biomass accumulation determines the predicted success of ecosystem recovery on disturbed soils.[3]

Technical Objective 3: Model Soil Organic Matter for Different Land Cover Types

The objective of this task was to use a simple compartment model of soil carbon and nitrogen dynamics to predict forest recovery on degraded soils and forest sustainability, following recovery, under different regimes of prescribed fire and timber management. The task included a model-based analysis of the effect of prescribed burning and forest thinning or clearcutting on stand recovery and sustainability at Fort Benning, GA. I developed the model using Stella® Research Software (High Performance Systems, Inc., Hanover, NH) and parameterized the model using data from field studies at Fort Benning, literature sources, and parameter fitting. The model included (1) a tree biomass submodel that predicted aboveground and belowground tree biomass (2) a litter production submodel that predicted the dynamics of herbaceous aboveground and belowground biomass (3) a soil carbon and nitrogen submodel that predicted soil carbon and nitrogen stocks (to a 30-cm soil depth) and net soil nitrogen mineralization, and (4) an excess nitrogen submodel that calculated the difference between predicted plant nitrogen demands and soil nitrogen supplies. There was a modeled feedback from potential excess nitrogen (PEN) to tree growth such that forest growth was limited under conditions of nitrogen deficiency.

Two experiments were performed for the model-based analysis. In the first experiment, forest recovery from barren soils was predicted for 100 years with or without prescribed burning and with or without timber management by thinning or clearcutting. In the second experiment, simulations began with 100 years of predicted forest growth in the absence of fire or harvesting, and sustainability was predicted for a further 100 years either with or without prescribed burning and with or without forest management. Four performance variables (aboveground tree biomass, soil carbon stocks, soil nitrogen stocks, and PEN) were used to evaluate the predicted

[3] Garten, C.T., Jr., and T.L. Ashwood. 2004b. Modeling soil quality thresholds to ecosystem recovery at Fort Benning, Georgia, USA (ORNL/TM-2004/41). Oak Ridge National Laboratory, Oak Ridge, TN.

effects of timber harvesting and prescribed burning on forest recovery and sustainability.

Predictions of forest recovery and sustainability were directly affected by how prescribed fire affected PEN. Prescribed fire impacted soil nitrogen supplies by lowering predicted soil carbon and nitrogen stocks, which reduced the soil nitrogen pool that contributed to the predicted annual flux of net soil nitrogen mineralization. On soils with inherently high nitrogen availability, increasing the fire frequency in combination with stand thinning or clearcutting had little effect on predictions of forest recovery and sustainability. However, experiments with the model indicated that combined effects of stand thinning (or clearcutting) and frequent prescribed burning could have adverse effects on forest recovery and sustainability when nitrogen availability was just at the point of limiting forest growth. Model predictions indicated that prescribed burning with a 3-year return interval would decrease soil carbon and nitrogen stocks but not adversely affect forest recovery from barren soils or sustainability following ecosystem recovery. On soils with inherently low nitrogen availability, prescribed burning with a 2-year return interval depressed predicted soil carbon and nitrogen stocks to the point where soil nitrogen deficiencies prevented forest recovery as well as forest sustainability following recovery.[4]

Technical Objective 4: Contribute to and Conduct Field Experiments on Ecosystem Disturbance

The purpose of this task was to examine the effects of heavy, tracked-vehicle disturbance on various measures of soil quality in training compartment K-11 at Fort Benning, Georgia. Predisturbance soil sampling in April and October of 2002 indicated statistically significant differences in soil properties between upland and riparian sites. Soil density was less at riparian sites, but riparian soils had significantly greater carbon and nitrogen concentrations and stocks than upland soils. Most of the carbon stock in riparian soils was associated with mineral-associated organic matter (i.e., the silt + clay fraction physically separated from whole mineral soil). Topographic differences in soil nitrogen availability were highly dependent on the time of sampling. Riparian soils had higher concentrations of extractable inorganic nitrogen than upland soils and also exhibited significantly greater soil nitrogen availability during the spring sampling.

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[4] Garten, C.T., Jr. Predicted effects of prescribed burning and timber management on forest recovery and sustainability in southwest Georgia. Journal of Environmental Management (In press)

The disturbance experiment was performed in May 2003 by driving a D7 bulldozer through the mixed pine/hardwood forest. Post-disturbance sampling was limited to upland sites because training with heavy, tracked vehicles at Fort Benning is generally confined to upland soils. Soil sampling approximately 1 month after the experiment indicated that effects of the bulldozer were limited primarily to the forest floor (O-horizon) and the surface (0-10 cm) mineral soil. O-horizon dry mass and carbon stocks were significantly reduced, relative to undisturbed sites, and there was an indication of reduced mineral soil carbon stocks in the disturbance zone. Differences in the surface (0-10 cm) mineral soil also indicated a significant increase in soil density as a result of disturbance by the bulldozer. Although there was some tendency for greater soil nitrogen availability in disturbed soils, the changes were not significantly different from undisturbed controls. It is expected that repeated soil disturbance over time, which will normally occur in a military training area, would simply intensify the changes in soil properties that were measured following a one-time soil disturbance at the K-11 training compartment.

The experiment was also useful for identifying soil measurements that are particularly sensitive to disturbance and therefore can be used successfully as indicators of a change in soil properties as a result of heavy, tracked-vehicle traffic at Fort Benning. Measurements related to total O-horizon mass and carbon concentrations or stocks exhibited changes that ranged from ≈25 to 75 percent following the one-time disturbance. Changes in surface (0-10 cm) mineral soil density or measures of surface soil carbon and nitrogen following the disturbance were less remarkable and ranged from ≈15 to 45 percent (relative to undisturbed controls). Soil nitrogen availability (measured as initial extractable soil nitrogen or nitrogen production in laboratory incubations) was the least sensitive and the least useful indicator for detecting a change in soil quality. Collectively, the results suggest that the best indicators of a change in soil quality will be found at the soil surface because there were no statistically significant effects of bulldozer disturbance at soil depths below 10 cm.[5]

[5] Garten, C.T., Jr., and T.L. Ashwood. 2004c. Effects of heavy, tracked-vehicle disturbance on forest soil properties at Fort Benning, Georgia (ORNL/TM-2004/76). Oak Ridge National Laboratory, Oak Ridge, TN.

Technical Objective 5: Analyze Spatial Patterns of Soil Carbon and Nitrogen for the Purpose of Predicting Potential Non-Point Nitrogen Sources on the Landscape

The purpose of this task was to spatially assess the amount of potential excess nitrogen on Fort Benning through the use of a GIS-based model of nitrogen cycle processes. The analysis was performed in the following steps: (1) development of a conceptual model to quantify potential excess soil nitrogen (PEN), (2) acquisition and recategorization of a land use/cover map of Fort Benning that was derived from Landsat Thematic Mapper data, (3) development of nitrogen flux maps for each of five nitrogen cycle processes by acquisition of field data and estimation of nitrogen fluxes under different land covers from a literature review, (4) calculation of seasonal and annual PEN using GIS-based spatial models, and (5) comparison of PEN between land use categories. The model predicted the spatial distribution of seasonal and annual nitrogen sources and sinks and estimated the amount of nitrogen flux using a mass balance model of three input processes (atmospheric nitrogen deposition, fertilization, net soil nitrogen mineralization) and two output processes (plant uptake and denitrification). Net soil nitrogen mineralization was the primary contributing process to annual and seasonal estimates of PEN. Potential excess nitrogen was positive (a potential source) when potential inputs exceeded potential outputs. Negative PEN indicated a potential sink. The results indicated that most of Fort Benning is a net sink for nitrogen; only 6 percent of the landscape was identified as a source of PEN. Positive PEN values were primarily associated with urban land uses, particularly roads and cantonment areas. Barren areas were also identified by the model as having positive PEN values. Information and experience obtained as a result of this technical objective will contribute to another SERDP Project (SERDP 1259) directed at developing a regional simulation model (RSim) to explore impacts of resource use and constraints in the five county region surrounding Fort Benning.

8 Final Report: Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics: CS 1114E

SERDP Ecosystem Management Project CS 1114E Executive Summary
Principal Investigator: Beverly Collins
Savannah River Ecology Laboratory

Introduction

Land at Fort Benning is used for multiple purposes. Current land use for military training ranges from light disturbance by foot and occasional light vehicle traffic to heavy disturbance by repeated armored vehicle traffic. Upland mixed pine/hardwood forests are thinned and periodically burned to promote longleaf pine (*Pinus palustris*) savanna for the endangered red-cockaded woodpecker (*Picoides borealis*). These land uses occur over a heterogeneous environment. The installation's location in the Fall Line Sandhills region is an ecotone between the Piedmont and Coastal Plain provinces. Vegetation and soils are influenced by topography, drainage, periodic fires, and a long history of human use. Some combinations of land uses may not be sustainable over upland environments at Fort Benning. The ecosystem may lose nutrients or fail to regenerate desirable species. Objective 3 of FY2000 SON (CSSON-00-03) requested research to 'determine whether there are thresholds in spatial extent, intensity or frequency above and/or below which the natural system cannot sustain identified ecological and/or land use disturbances.' The Savannah River Ecology Laboratory (SREL) conducted a field experiment to evaluate the ecological effects of military training and forest management for longleaf pine at Fort Benning, to determine if there are thresholds beyond which upland ecosystems cannot sustain the combined effects of these land uses.

This research was conducted from 2000 through 2004 in 32 upland forest stands at Fort Benning. We manipulated the frequency of prescribed fire to a) an accelerated 2-yr interval or b) a delayed 4-yr interval, and compared ecosystem responses between sites on sandy vs clayey soil and in lighter training (primarily dismounted infantry) vs heavier training (compartments open to mechanized training) area. We compared ground-layer vegetation and nitrogen cycling over 5 years, which encompassed two 2-yr fire intervals and one 4-yr fire interval, to determine if these measures show thresholds beyond which combinations of military training and prescribed fire cannot be sustained.

Longleaf pine ecosystem is the desired future condition for upland forests on appropriate sites at Fort Benning. Under the assumption that a short (2-yr) fire interval is the external force that sustains longleaf ecosystem, sandy or clay longleaf-dominated sites with lower or higher military use and in the 2-yr fire treatment provided ‘control’ or threshold values for transition to the longleaf ecosystem domain. We hypothesized that the more open environment generated by heavier training and frequent fire could promote regeneration of species typical of pine ecosystems, and hasten transition to a longleaf pine forest, provided species tolerate the disturbance legacy of mechanized military training. We also hypothesized that the magnitude of ecosystem response to fire and military training disturbance would be less, and the transition to pine-dominated forest faster, for sites on sandy soils because the pool of tolerant species is smaller and the successional pathway is shorter on these lower quality soils.

Baseline surveys conducted in 2000 and 2001 revealed that vegetation and soil conditions at the start of this research reflected land use and soil texture differences among the study sites.

A survey of disturbance features revealed that land use or natural disturbance features occupied from 7 to 50 percent of sample transect length. Clayey sites in heavy military use areas had greater length of sampling transects in disturbance features. Road-like features, including active and remnant trails, roads, and vehicle tracks or trails, were, collectively, the most frequent and abundant disturbance.

Differences in soil properties among the 32 upland forest stands were related to soil texture and military land use intensity. Results suggest organic layers in sandy compared to clayey sites could immobilize nitrogen through relatively slow rates of decomposition and nitrogen release to the mineral soil In the mineral soil, field and laboratory results suggest that mineralization processes enhance nitrogen availability in sandy sites, especially in land compartments with heavier military training. In contrast to the sandy sites, greater organic layer mass in clayey sites, particularly in sites with lighter military use, favors faster decomposition, but the lower nitrogen availability observed in the field on the heavier use sites suggests mineralized nitrogen can be bound by fine soil particles.

Ordination, used to visualize patterns in vegetation composition, revealed a strong effect of military training on canopy and ground layer composition at the start of this research. The canopy tree ordination also reflected the proportion of pine, particularly longleaf pine. We distinguished four forest types, based on the dominant canopy trees: longleaf pine stands, shortleaf stands, mixed pine hardwood stands, and loblolly stands. Although differences were less pronounced than in the canopy, ground layer vegetation also reflected the canopy dominant. Pine-hardwood and longleaf stands had different ground layer composition. *Andropogon* sp., primarily broomsedge, *A. virginicus*, *Pityopsis*, and sweetgum (*Liquidambar*) seedlings were abundant in multiple canopy types. Pine-hardwood forests had abundant *Vitis* sp, while bracken fern (*Pteridium aquilinum*) was abundant in longleaf stands. The abundance of legumes and grasses was higher in the longleaf stands than in the other forest types. Over all forests types, 70 percent pine canopy appears to be a threshold for ground layer vegetation with abundant grasses and legumes.

Vegetation analyses after two 2-yr fire cycles and one 4-yr cycle revealed the shorter, 2-yr fire interval caused the ground layer vegetation to become more similar to that of clayey sites with heavier military use; i.e., to be characterized by more xeric sandhills species and nonwoody legumes, graminoids, and forbs. However, comparisons of ground layer composition between longleaf stands and those of the combined other (pine-hardwood, shortleaf, loblolly) forest types revealed that sites that were initially different did not converge over time. The shorter, 2-yr fire interval did not cause initially dissimilar sites to become more similar to, or initially similar sites to diverge from, longleaf communities. Although the shorter fire interval did not cause dissimilar sites to shift to longleaf, either 1) heavier military use or shorter fire frequency in clayey sites, or 2) shorter fire frequency in sandy sites can maintain ground layer composition similar to that of longleaf sites. These results partially support our hypothesis that the magnitude of ecosystem response to fire and military training disturbance would be less, and the transition to pine-dominated forest faster, for sites on sandy soils. Shorter fire frequency alone can maintain longleaf ground layer composition on sandy sites, but both shorter fire frequency and heavier military training may be needed in clayey sites.

Within the context of Fort Benning ecosystem management model, the longer, 4-yr fire intervals in sandy sites or the combination of longer fire interval and lighter military use in clayey sites may cause sites to move away from the longleaf domain and lengthen the successional trajectory. In contrast, a 2-yr fire interval and heavier military use in clayey sites or the 2-yr fire interval in sandy sites may maintain sites within the desired longleaf understory domain. However, in sampled stands the more frequent burning did not result in high levels of legume abundance and associated N inputs, which could offset nitrogen losses due to fire. Further, more frequent burning did not promote longleaf regeneration sufficient to hasten transition to a longleaf pine forest. Longleaf regeneration was absent to low over all sites. Over half (57 percent) of marked pine seedlings (all species combined) died between 2001 and 2002; mortality was higher in longleaf stands and 2-yr fire frequency. Thus, despite promoting desirable understory composition, more frequent fire may inhibit regeneration. These results only partially support our hypothesis that the more open environment generated by heavier training and frequent fire could promote regeneration of species typical of pine ecosystems, and hasten transition to a longleaf pine forest. If seedling establishment limitation is overcome, e.g., by planting, management that maintains a relatively open canopy (prescribed fire, thinning) and low soil disturbance (lighter compared to heavier military training), can promote growth into grass, rocket, and sapling stages. In summer, 2004, after all sites were burned following both 2-yr fire intervals and one 4-yr fire interval, the number of grass stage individuals in a stand increased with the number of historical fires (1980-2000), longer time since fire, and the percent of sand in the soil; the number of rocket stage individuals increased with increasing number of historical fires. These conditions were common in longleaf and shortleaf stands that had experienced higher fire frequency and forest management for an open canopy, but lighter military use.

In summary, military training and frequent fire have, over the longer term (decades), interacted with soil texture to influence forest canopy and ground layer composition, and soil conditions, at Fort Benning. Over the shorter term of our research (4 years), frequent fire (on sandy sites), or frequent fire combined with heavier military use (on clayey sites) can cause convergence toward ‘sandhills’ ground layer vegetation dominated by more xeric species, graminoids, and legumes, but these land uses are not sufficient to cause initially dissimilar sites to shift (cross a threshold) to longleaf pine understory. Management to restore longleaf pine forests must overcome recruitment limitations and may be inhibited by frequent fire; recruitment of longleaf was nonexistent to low over all sites and seedlings/sprouts of all species were reduced by prescribed fire. If recruitment limitation is overcome, management that maintains a relatively open canopy and low soil disturbance can promote longleaf pine growth into grass, rocket, and sapling stages and may facilitate restoration of longleaf pine ecosystem as conceptualized in the Fort Benning ecological restoration model.

9 SEMP Ecosystem Characterization and Monitoring Initiative (ECMI) Annual Report 2005

SERDP Ecosystem Management Project (CS-1114)
Principal Investigator: Dr. David L. Price, ERDC-EL

Aquatic Biology Monitoring

Benthic macroinvertebrate samples and data describing environmental and physical habitat parameters were collected at Fort Benning stream sites during both Spring and Fall 2004 as well as in Fall 2005. Spring 2004 sampling occurred at 9 sites in 5 streams (2nd-5th order) associated with construction of the new Digital Multi-purpose Range Complex (DMPRC). Sampling in the Fall 2004 occurred at 12 sites in 11 streams (2nd-6th order); 5 of these sites were located in streams potentially affected by DMPRC construction activities. During Fall 2005, 5 of 12 total sites were located outside the DMPRC zone.

At each 100-m site, standard Rapid Bioassessment Protocol scores were used to characterize physical habitat quality.[1] Environmental data describing pH, turbidity, conductivity, and dissolved oxygen concentration also were collected to examine water quality conditions. Benthic macroinvertebrates were sampled at each site to indicate biological variability among streams.

Spring 2004

The specific streams sampled included Sally Creek (3 sites), Pine Knot Creek (2 sites), a tributary of Pine Knot Creek, Bonham Creek (2 sites), and a tributary to Bonham Creek (Figure 9-1). The purpose of this effort was to gather pre-construction data that might be useful in making a post-project evaluation of stream impacts.

[1] Barbour, M.T., Gerritsen, J., Snyder, B.D., and Stribling, J.B. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish, 2nd Ed., EPA 841-B-99-002, U.S. Environmental Protection Agency, Washington, DC.

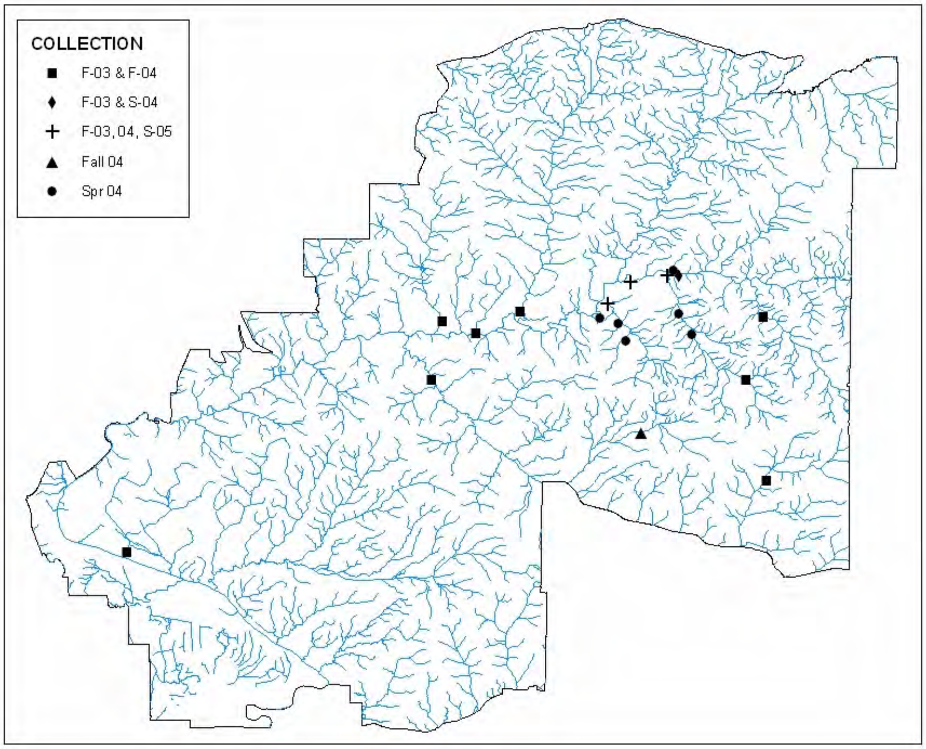


Figure 9-1. Sampling locations on Fort Benning streams Fall 2003-Fall 2004.

All of the DMPRC sampling sites were located within a relatively small coastal plain section of the base. As expected, pH was similar among these sites (ph=4.9-6.1; Table 9-1). Instream deposition of loose sand was prevalent at the Pine Knot tributary site (RBP=147); RBP scores were similar among the other 8 sites (150-159; Figure 9-2). RBP scores are positively correlated with physical habitat quality (greater scores indicate better physical habitat quality).

Benthic macroinvertebrates were sampled from each substantial habitat type represented at a site; stratified samples weighted by habitat abundance were combined into a sample composite prior to processing. A direct count of 250 + 10 percent organisms were then randomly removed from the composite material and identified to genus when possible, except chironomids and oligochaetes. Two types of calculations were used to provide biological indicators of habitat conditions for each site.

Table 9-1. Summary data of eight major metrics associated with evaluating stream quality at Fort Benning Fall 2003-Fall 2004.

			No. of Taxa	Taxa Richness	HBI score	EPT taxa	% EPT	% Chi-ronomids	RBP score	pH
Bonham Cr	Bon01	Fall 03	234	22	6.55	10	14.1	33.8	145	5.04
		Spr 04	252	22	5.36	7	21.8	54.4	150	5.05
		Fall 04	190	46	5.51	11	15.8	67.4	147	3.53
Lower Sally Br	Sal01	Fall 03	251	17	5.83	8	6.4	82.9	145	4.58
		Spr 04	249	14	6.19	2	2.4	78.7	152	4.96
		Fall 04	184	44	5.94	9	8.1	70.3	146	3.57
Upper Sally Br	Sal04	Fall 03	251	20	6.13	3	11.6	39.4	141	6.01
		Fall 04	158	34	6.32	5	6.3	47.5	143	4.79
Upper Pine Knot Cr	PKC02	Fall 03	252	21	6.05	12	18.7	35.7	154	4.71
		Spr 04	250	17	6.16	7	7.6	66.4	157	4.90
Lower Pine Knot Cr	PKC01	Fall 03	232	21	6.07	8	15.5	43.5	159	4.55
		Spr 04	240	18	5.87	5	10.8	65.0	158	5.00
		Fall 04	194	49	5.36	12	31.2	42.9	160	3.17
Wolf Cr	Wolf01	Fall 03	260	18	5.90	4	7.7	74.2	152	5.35
		Fall 04	190	41	5.35	10	18.4	53.2	154	3.72
Randall Cr	Rand01	Fall 03	244	14	6.25	3	5.3	70.5	122	7.18
		Fall 04	144	29	6.85	4	6.3	45.1	123	5.25
Little Pine Knot Cr	LPK01	Fall 03	252	22	5.49	9	25.0	43.3	158	4.00
		Fall 04	176	35	4.54	13	43.1	52.3	159	3.76
Laundry Cr	Laun01	Fall 03	250	14	5.90	4	24.4	34.8	148	5.95
		Fall 04	198	37	5.39	8	34.9	28.8	148	4.30
Ochille Cr	Och01	Fall 03	249	17	5.59	8	28.9	41.4	160	6.60
		Fall 04	175	34	5.52	11	28.0	28.6	162	4.70
Upatoi Cr	Upat01	Fall 03	237	11	7.43	3	2.5	25.3	162	5.92
		Fall 04	167	42	6.13	14	22.2	35.9	164	5.10
Hollis Cr	Hol01	Fall 03	253	18	5.88	8	12.3	68.4	149	5.43
		Fall 04	171	34	6.26	8	8.8	63.2	150	3.74
Bonham Cr	Bon02	Spr 04	252	13	6.82	0	0.0	62.3	156	5.23
Sally Br	Sal02	Spr 04	243	16	6.48	3	9	48.2	154	5.89
Middle Sally Br	Sal03	Spr 04	246	14	5.23	2	27.2	42.3	159	4.92
Trib to PKC	PKC Trib01	Spr 04	248	18	4.34	4	39.5	39.5	147	6.12
Trib to Bonham	Bon Trib 01	Spr 04	253	12	6.17	4	2.8	83.8	158	5.03
Hallaca Cr	Hall 01	Fall 04	253	21	6.81	3	4.3	70.0	148	4.64

First, environmental tolerance values were used to calculate mean tolerance values (IBI) for organisms collected at each site.[2] Low IBI scores indicate low tolerance to environmental perturbation, whereas high IBI scores are indicative of organisms often associated with degraded or poor habitats. Second, organisms of the taxanomic orders Ephemeroptera, Plecoptera, and Trichoptera are generally considered “intolerant” to environmental perturbation. Therefore, %EPT and IBI, which are expected to be negatively correlated, were used to indicate relative differences in habitat quality among sites.

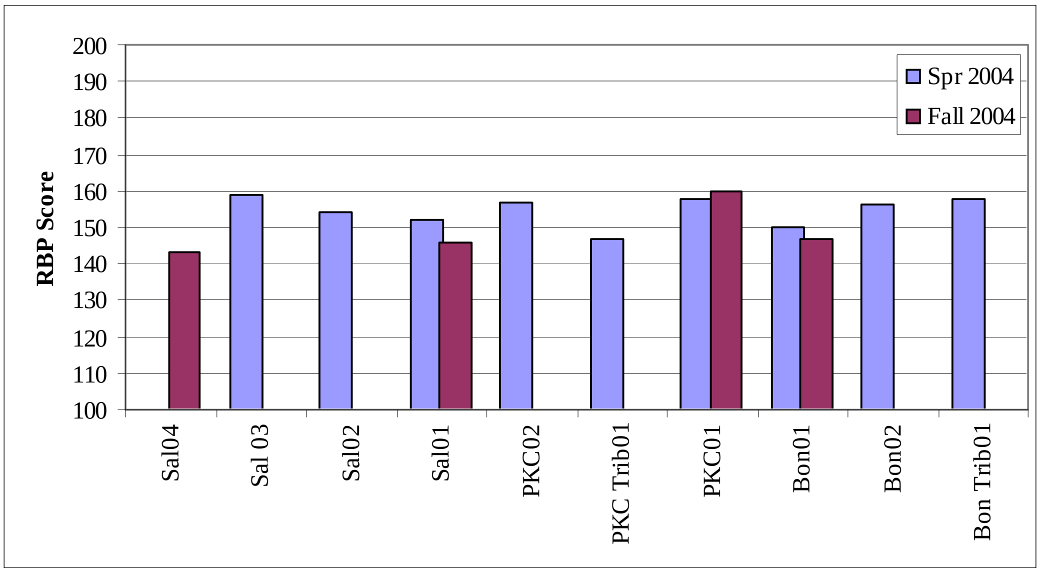


Figure 9-2. Rapid Bioassessment (RBP) scores for physical habitat at DMPRC sites.

There were consistent differences in IBI and %EPT among sites of different creek systems (Figure 9-3 and Figure 9-4). The three Sally Creek sites had both relatively high IBI scores and the lowest %EPT estimates among all sites; these results indicate that relative habitat quality in Sally Creek is lower than in Pine Knot Creek and Bonham Creek. IBI and EPT estimates from within the Bonham Creek drainage indicated higher habitat quality relative to the other two creek systems. These differences in calculated IBI and %EPT among stream systems can be attributed to differences in relative abundance of early instar Chloroperlidae mayflies. Chloroperlids were much more common in samples from the Bonham Creek sites (27-88 indi-

[2] Barbour, M.T., Gerritsen, J., Snyder, B.D., and Stribling, J.B. (1999). Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish, 2nd Ed., EPA 841-B-99-002, U.S. Environmental Protection Agency, Washington, DC.; North Carolina Department of Environment and Natural Resources (2003). Standard operating procedures for benthic macroinvertebrates. Unpublished report by NCDENR, 44 pp.

viduals) than those from Pine Knot (8-18) and Sally Creek (0-4) sites. Since chloroperlids are of the Order Ephemeroptera and have a very low environmental tolerance value (1), differences in their abundance among stream sites directly affected both IBI and %EPT scores.

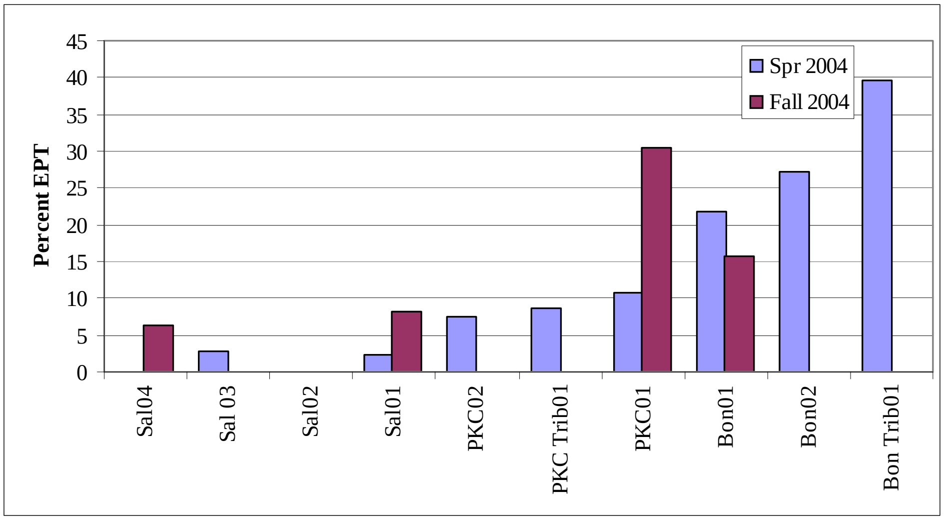


Figure 9-3. Percentage of Ephemeroptera-Plecoptera-Tricoptera in samples collected from streams within the DMPRC zone during Spring and Fall 2004.

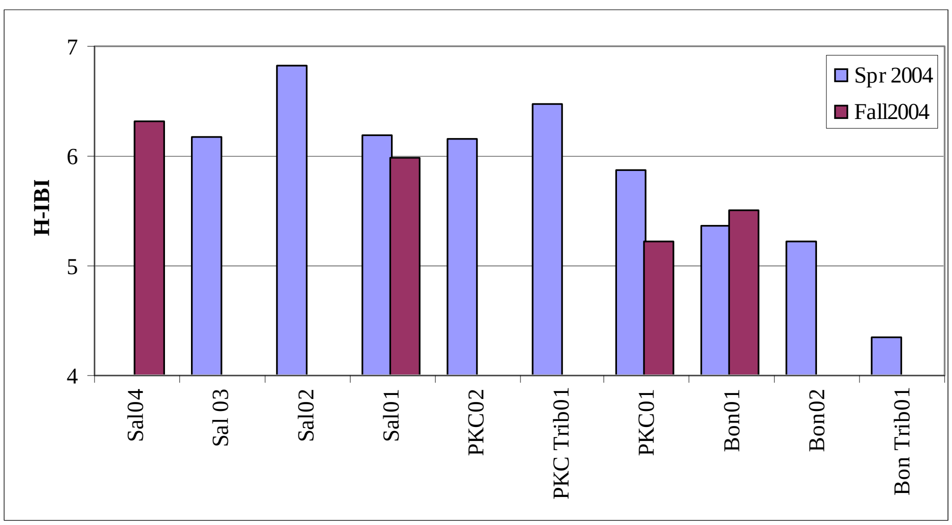


Figure 9-4. Index of biotic integrity scores for samples collected from DMPRC stream sites during Spring and Fall 2004.

Fall 2004

Methods similar to those used in Spring 2004 were used to sample 12 sites. Five of these sites were located within streams associated with construction activities for the DMPRC (one site in each of Bonham, Pine Knot, and Little Pine Knot Creeks, as well as two Sally Creek sites). Selected sites in Randall, Ochillee, Wolf, Upatoi, Hollis, Laundry, and Hallaca Creeks also were sampled during Fall 2004.

Although most methods used to obtain Spring and Fall 2004 were identical, chironomids in Fall samples were identified to genus. Results indicated a similar, although not as clear, indication that stream quality in Bonham Creek is greater than Pine Knot and Sally Creeks (Figure 9-3 and Figure 9-4; Table 9-2). Sally Creek, in particular, had both low %EPT and high IBI scores.

Taxonomic identification of chironomids to the generic level allowed us to 1) compare HBI averages calculated using scores at the Family and Genus level of taxonomic level of resolution, and 2) calculate a Georgia IBI estimate for each stream.

Table 9-2. Summary data for Fort Benning stream sites sampled during Fall 2004.

	Total Org.	EPT %	% Chiro	RBP	pH	HBI	G-IBI
Bonham Cr	190	15.8	67.4	147	3.53	5.16	27
Lower Sally Br	184	8.2	70.1	146	3.57	5.76	27
Upper Sally Br	158	6.3	47.5	143	4.79	6.04	27
Lower Pine Knot Cr	194	30.4	41.8	160	3.17	5.37	27
Wolf Cr	190	18.4	53.2	154	3.72	5.35	25
Randall Cr	144	6.3	45.1	123	5.25	6.85	21
Little Pine Knot Cr	176	42.6	52.8	159	3.76	4.51	27
Laundry Cr	198	34.8	28.8	148	4.30	5.29	31
Ochille Cr	175	28.0	28.6	162	4.70	5.34	31
Upatoi Cr	167	22.2	35.9	164	5.10	6.02	27
Hollis Cr	171	8.8	63.2	150	3.74	6.21	23
Hallaca Cr	253	4.3	70.0	148	4.64	6.81	15

How does taxonomic resolution affect IBI scores?

There were no great differences between IBI estimates based on generic and family-level identifications of chironomids (Figure 9-5). The two largest differences in estimates occurred with samples collected at Hallaca Creek and a Bonham Creek site. However, the Hallaca Creek estimates were higher (poorer quality) with generic level identifications of chironomids, whereas the Bonham Creek estimates were lower (greater quality) using generic identifications. Based on these initial results, it appears that more costly and time-consuming generic-level identifications of chironomids may not be necessary to assess or monitor stream quality at Fort Benning.

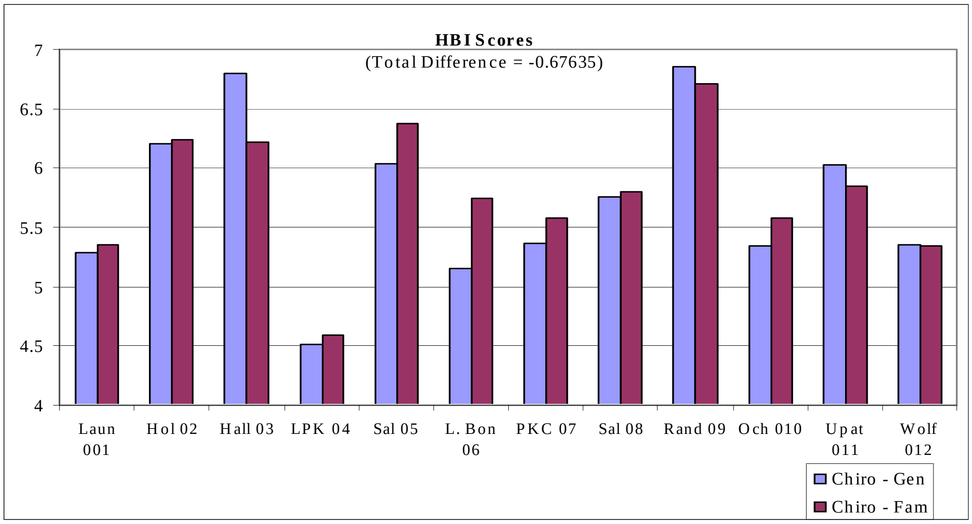


Figure 9-5. Comparison of Hilsenhoff biotic index scores for samples collected from Fort Benning streams during Fall 2004. Estimates are based on scores calculated separately using generic and family-level identifications of Chironomidae.

Georgia Index of Biotic Integrity

The Georgia Department of Natural Resources has developed a method for estimating relative stream quality based on macroinvertebrate assemblage characteristics in Georgia streams. The Georgia Index of Biotic Integrity (Ga-IBI) uses commonly accepted metrics to compare characteristics of a stream's benthic macroinvertebrate assemblage with those with other streams in the same region of the state. The categories are:

Very Good	Comparable to best situation to be expected; species with endangered, threatened, or special concerns.	35-31
Good	Balanced community with sensitive species present.	30-25
Fair	Expected species absent or in low abundance; few sensitive species present.	24-19
Poor	Low species richness, with tolerant species predominant, sensitive species absent.	18-14
Very Poor	Expected species absent, having only tolerant organisms present with few or no EPT taxa.	< 14

Scores for Fort Bennings streams were relatively high and indicated overall good stream quality (Table 9-3). Lower scores in Randall, Hollis, and Hallaca Creeks were the result of either low numbers of EPT taxa, high percentage of dominant taxa (usually chironomids), or overall taxa richness. Only Hallaca Creek was classified as "very poor" using these methods.

Table 9-3. Summary of data metrics used to estimate Ga-IBI scores for Fort Benning streams.

	Taxa Richness	EPT Index	Number Chiro Taxa	% Dom Taxa	% Dip	FL Index	% Filter-ers	Ga-IBI Score	Ecological Condition
Bonham Creek	5	5	5	5	1	5	1	27	Good
Lower Sally Branch	5	5	5	3	1	5	3	27	Good
Upper Sally Branch	5	3	5	5	1	3	5	27	Good
Lower PKC	5	5	5	5	1	5	1	27	Good
Wolf Creek	5	5	5	3	1	5	1	25	Good
Randall Creek	3	3	5	3	1	1	5	21	Fair
Little Pine Knot Cr.	5	5	5	5	1	5	1	27	Good
Laundry Creek	5	5	5	5	3	3	5	31	Very Good
Ochille Creek	5	5	5	5	3	3	5	31	Very Good
Upatoi Creek	5	5	5	5	1	3	3	27	Good
Hollis Creek	5	5	5	3	1	3	1	23	Fair
Hallaca Creek	3	1	5	1	1	3	1	15	Very Poor

Fall 2005

Seven sites were sampled along four DMPRC streams (Pine Knot, Little Pine Knot, Bonham, and Sally Creeks; Figure 9-6). Data also were collected at sites in 5 additional streams outside the DMPRC zone (Laundry, Wolf, Randall, Upatoi, and Ochillee Creeks).

As expected, pH was lowest at sites located within the DMPRC zone (Figure 9-7). These streams (i.e., Bonham, Little Pine Knot, Pine Knot, and Sally) typically have the lowest pH among all Fort Benning streams. Conversely, the highest pH measurement was taken in Randall creek. Upland streams at Fort Benning typically have pH near to, or exceeding, neutral.

Rapid Bioassessment Protocol scores (RBP) provide an indication of physical habitat quality. The Randall Creek site had the lowest RBP score (120; Figure 9-8). Substrate within Randall consists of loose, shifting sand and very little instream stable habitat; channel sinuosity, pool development, depth diversity, and instream cover also are very low in most of the upland streams at Fort Benning. These characteristics all contribute to the low RBP score for Randall. Streams within the DMPRC area of the base all have moderate RBP scores. Depth diversity and pool development are much more prevalent in these streams than in upland streams on the base. However, high depth diversity, pool development, and the abundance of stable substrate (mainly large woody debris) in Ochillee and Upatoi Creeks explains the higher RBP scores for those two systems (Figure 9-6).

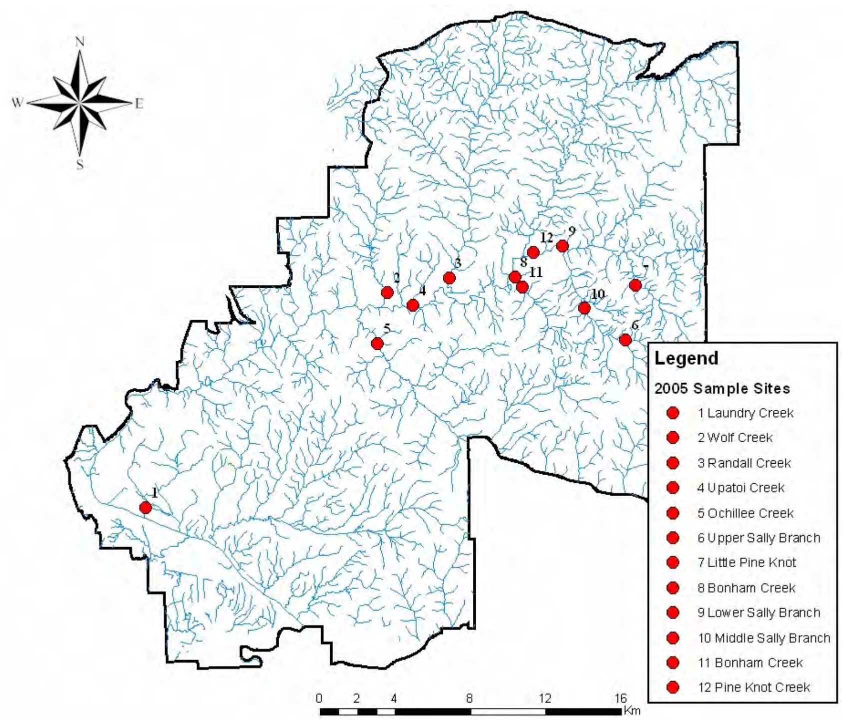


Figure 9-6. Location of sample sites on Fort Benning Military Reservation, Fall 2005.

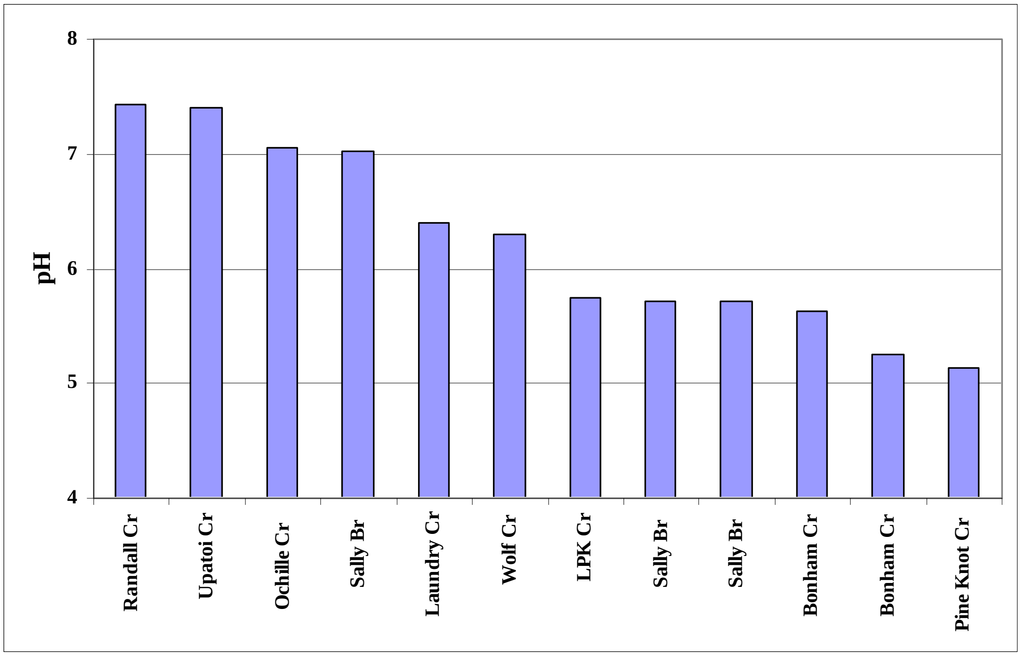


Figure 9-7. Variability in pH among sites sampled, Fall 2005.

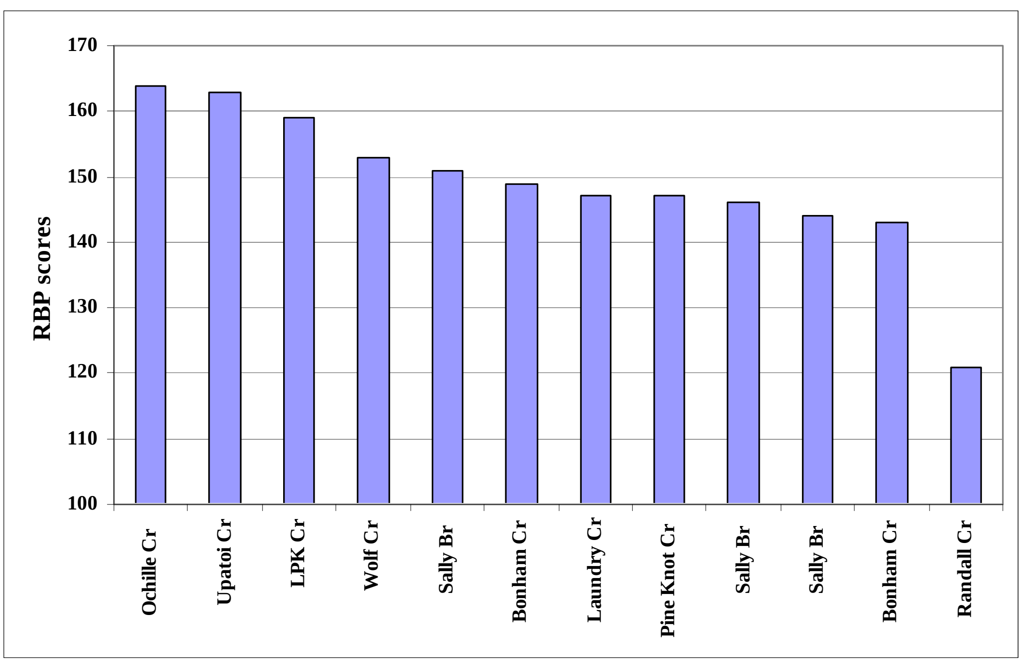


Figure 9-8. Rapid Bioassessment Protocol scores for stream sites sampled, Fall 2005.

Summary

Physical habitat and water chemistry results indicate relatively stable habitat conditions among most Fort Benning streams. However, the results from Spring and Fall 2004 actually represent pre-DMPRC project conditions. Logging and construction activities near our sampling locations had commenced just prior to our visit during Fall 2004. Possible ecological changes in stream condition associated with DMPRC construction activities will probably become detectable with our final analyses of Fall 2005 biological data (IBI) as well as all survey results in Fall 2006.

Our results also indicate the importance of using multiple metrics when working at multiple spatial scales. Physical habitat and water chemistry may differ among streams at a large, base-wide scale. However, biological metrics were more useful when comparing the DMPRC streams, which all have very similar physical habitat.

Meteorology, Surface, and Ground Water Monitoring

The Ecosystem Characterization and Monitoring Initiative (ECMI) consisted of collecting ecosystem data representing annual profiles that characterize ecosystems of meteorological, stream water quality, and ground water. The meteorological data consisted of daily readings on the parameters of Air Temperature, Relative Humidity, Barometric Pressure, Solar Radiation, Wind Speed, Wind Direction, and Precipitation; whereas the stream water quality represented stream water quality characterizations as measured by the parameters of Dissolved Oxygen, pH, Specific Conductance, Water Temperature, NO3 and Turbidity. Ground water data characterized two parameters – Water Temperature and the distance from the Top of the Casing to the Water Surface.

The meteorological data were consistently collected every 30 minutes each day at 10 meteorological sampling stations over a period of 5 years beginning on 13 August 1999 and ending 01 July 2004. The meteorological sampling window represented 3,566 daily readings; however, for this report only the sampling dates beginning on 01 January 2001 and ending 01 July 2004 were selected in order to coincide with the sampling windows for both the water quality and ground water data collection activities. Daily readings were measured and recorded every 30 minutes throughout the duration of the study and summarized as minimum daily temperature, average daily temperature, maximum daily temperature, average barometric pressure, average relative humidity, average wind speed, total precipitation, and maximum solar radiation. In total, 10,652 summary observations were recorded and archived. The 10 sampling stations were positioned to represent the entire installation located at Fort Benning, GA.

The water quality data were collected at five locations designated as Bonham Creek, Little Pine Knot, Oswichee Creek, Randall Creek, and Upatoi Creek. The 601 observations were collected on a bi-weekly sampling plan beginning on July 25, 2001 and ending on June 21, 2004.

The ground water data were collected at four locations: Little Pine Knot, Oswichee Creek, Randall Creek, and Sally Branch. The data were collected on a daily basis from 16 January 2001 through 22 April 2003 and then monthly from 06 May 2003 through 07 June 2004. In total, 2,353 observations were recorded at these locations and sampling times.

Descriptive Statistics: Meteorological Profiles

Appendix A presents a more detailed statistical analysis of the meterological observations acquired in the sampling period 2001-2004. Selected elements from the meterological sampling are presented here.

Statistical Analyses: Meteorological Sampling Effort

Analysis of the meteorological parameters of barometric pressure, surface air temperatures, wind speeds, and maximum solar radiation, all indicated that site and seasonal differences were present; whereas, total precipitation only exhibited differences among seasons. Table 9-4 summarizes the findings of the analysis of variance for each of these parameters.

Table 9-4. Analysis of Variance for Meteorological Parameters.

Parameter	Site		Season	
	F-value	p-value	F-value	p-value
Barometric Pressure	837.97	<0.0001	79.17	<0.0001
Air Temperature	2.20	0.0191	4613.52	<0.0001
Wind Speed	136.38	<0.0001	226.46	<0.0001
Solar Radiation	58.80	<0.0001	1479.44	<0.0001
Total Precipitation	1.58	0.1139	6.47	0.0002

The analysis of variance indicated that significant differences among barometric pressure readings were observed among the 10 meteorological satiations ($F= 837.97$, p-value < 0.0001) and among seasons ($F = 79.17$, p-value < 0.0001). Met Station 2 exhibited the lowest average BP of 1009.93 mg Hg, whereas, Met Station 10 exhibited the highest reading of 1025.55 mg Hg. With regard to seasons, the winter sampling period exhibited he highest BP average of 1018.88 mg Hg; the summer and spring periods exhibited the lowest reading of 1017.51 and 1017.41mg Hg, respectively.

As with barometric pressure, the average surface air temperature regimes also exhibited significant differences among sampling stations ($F=2.20$, p-value $= 0.0191$) and seasons ($F = 4613.52$, p-value < 0.001). Tukey's HSD test indicated mixed conclusions for most of the monitoring stations. Met Station 5 exhibited the highest mean temperature readings of 17.78°C; whereas, Met Station 9 had the lowest mean temperature reading of 16.84°C. With regard to seasons, the average for each season was all statistically different, as would be expected. The mean temperatures were 25.31°C, 20.18°C, 15.05°C, and 9.45°C for Summer, Spring, Fall, and Winter, respectively.

Wind speeds averages ranged from a minimum of 0.60 m/s at Met Station 3 and a maximum of 1.35 m/s at Met Station 10. The data, as with the other Met parameters, indicated that differences among sampling stations ($F=136.38$, p-value < 0.0001) and seasons ($F=226.45$, p-value < 0.0001) were present. The average wind speeds were the highest in winter (1.12 m/s) and lowest in the summer (0.73 m/s). The Fall and Spring sampling periods exhibited average wind speeds of 0.95 m/s and 0.93 m/s, respectively.

The Met parameter of Maximum Solar Radiation further indicated that differences among sampling stations ($F=58.80$, p-value < 0.0001) and seasons ($F = 1479.44$, p-value < 0.0001) were present. The highest maximum solar radiation readings were observed at Met Station 4; the lowest maximum solar radiation readings were observed at Met 9. Additionally, the highest maximum solar radiation readings were observed during the summer (815.55 w/s^2) and spring season (806.83 w/s^2); the lowest readings were observed during the Fall (558.84 w/s^2) and Winter seasons (548.15 w/s^2).

Total precipitation did not exhibit any differences among the means at the various sampling stations (F=1.58, p-value = 0.113); however, differences among seasons were present (F=6.47, p-value = 0.0002). The average total precipitation ranged from a minimum of 2.28 mm to 3.42 mm. The overall average total daily precipitation was 2.88 mm. The highest amounts of precipitation were observed in the Winter season (3.44 mm) and the Summer season (2.99 mm); whereas, the lowest amounts were noted during the Spring season (2.58 mm) and the Fall season (2.45 mm).

Statistical Analysis: Stream Water Quality

Analysis the water quality parameters of dissolved oxygen, pH, specific conductance, surface water temperatures, nitrates, and turbidity all indicated that site and seasonal differences were present. Table 9-5 summarizes the findings of the analysis of variance for each of these parameters.

Table 9-5. Analysis of Variance for Stream Water Quality.

Parameter	Site		Season	
	F-value	p-value	F-value	p-value
Dissolved Oxygen	4.09	0.0012	183.3	p0.001
pH	295.87	<0.0001	11.12	< 0.0001
Specific Conductance	32.06	<0.0001	11.35	<0.0001
Water Temperature	12.86	< 0.0001	341.28	<0.0001
NO_3	15.07	<0.0001	8.31	<0.0001
Turbidity	20.08	<0.0001	10.14	<0.0001

Dissolved Oxygen highest readings were observed at Randall Creek (9.03), Oswichee Creek (8.66) and Sally Branch (8.64); whereas, the lower values were observed at Bonham Creek (8.50), Upatoi Creek (8.50) and Little Pine Knot (8.26). Tukey's hsd test indicates that the observed average at Randall Creek was significantly higher than the averages observed at Bonham Creek, Upatoi Creek, and Little Pine Knot. The observed averages at Oswichee Creek and Sally Branch were not different for either of the aforementioned two groups. Dissolved Oxygen content was highest during the winter seasons (10.33) and lowest during the summer season (7.07). All of the averages for each season were significantly different for one another. During the fall and spring months, the averages were 8.90 and 8.16, respectively.

The water quality parameter of pH was highest at Randall Creek (6.70) and lowest at Little Pine Knot (4.45), Bonham Creek (4.40), and Sally Branch (4.36). Upatoi creek exhibited an average reading of 5.93; Oswichee Creek pH value averaged 4.93. The highest pH values were observed during the Summer season (5.13) and the lowest readings were observed during the Winter months (4.78). The observed values for Fall and Winter were 5.01 and 4.89, respectively.

Specific Conductance readings exhibited the highest values at Randall Creek (28.42 µS) and the lowest readings at Sally Branch (5.79 µS). The other averages were 13.79 µS at Upatoi, 11.06 µS at Oswichee Creek, 8.58 µS at Little Pine Knot, and 6.90 µS at Bonham creek. As with pH, the highest Specific Conductance readings were observed during the Winter sampling months (14.46) and the lowest were observed during the Spring sampling months (6.36). During the Fall sampling period, the average was 13.82 µS; whereas, during the Summer the average was 9.98 µS.

Surface water temperature values were the highest at Randall Creek (20.90°C) and the lowest at Little Pine Knot (16.92°C). Upatoi Creek's average water temperature was 18.95°C; whereas, the other sampling locations yielded temperature regimes that centered around means of 18.06°C, 17.76°C, 17.20°C, respectively for Sally Branch, Oswichee Creek, and Bonham Creek. The surface water temperature was the highest in the summer (25.15°C) and the lowest in the winter (11.05°C). During the spring the water temperature averaged 20.77°C; whereas, during the fall the average was 15.36°C. The averages for each season were significantly different from each other.

Nitrate (NO_3) exhibited the highest concentrations at Randall Creek (3.17) and the lowest at Sally Branch (0.0003). The highest concentrations of NO_3 were observed during the summer months (1.26) with the lowest occurring during the winter months (0.0009).

Turbidity exhibited the highest concentrations at Randall Creek (156.58 national turbidity units - NTUs) and the lowest at Bonham Creek (24.22 NTUs), Little Pine Knot (16.27 NTUs), and Sally Branch (NTUs). Upatoi and Oswichee Creek exhibited concentrations of 98.5 NTUs and 94.35 NTUs, respectively. These three groupings were deemed different by Tukey's HSD test. Additionally, the highest concentrations of turbidity occurred during the winter months (85.46 NTUs); the other sampling periods of summer, spring, and winter exhibited average values of 44.36 NTUs, 43.74 NTUs, and 23.00 NTUs, respectively.

Statistical Analysis: Ground Water

Analysis of the ground water parameters of water temperature and the distance from the top of the casing to the surface of the water both indicated that site and seasonal differences were present. Table 9-6 summarizes the findings of the analysis of variance for each of these parameters.

Water temperature differences were noted at each of the four sampling sites of Oswichee Creek, Little Pine Knot, Randall Creek, and Sally Branch. The average temperatures at each of these sites were 19.36°C, 18.72°C, 18.45°C, and 17.22°C, respectively, and each of these average readings were significantly different from each other. The seasonal averages were 19.85°C, 19.20°C, 17.29°C, and 16.82°C, respectively for the fall, summer, winter, and spring sampling months, and as with the locations, Tukey's HSD procedure indicated that all means were different.

Table 9-6. Analysis of Variance for Ground Water.

Parameter	Site		Season	
	F-value	p-value	F-value	p-value
Water Temperature	1033.32	<0.0001	2722.58	<0.0001
Distance for top of casing to Water Level	15899.8	<0.0001	680.78	<0.0001

The distance from the top of the casing to the water surface level also exhibited differences in both locations and seasons. The distances ranged from a maximum average distance of 4.35 meters at Oswichee Creek to a minimum average of 2.63 meters at Sally Branch. Randall Creek and Little Pine Knot exhibited average distances of 2.98 and 2.69 meters, and as with the temperature regimes, Tukey's HSD test indicated that each of these means were different. The season differences were not as pronounced as the site differences; however the largest distance of 3.89 m was observed during the summer sampling season; whereas the smallest distances were observed during the spring (3.08 m) and the winter (3.08 m) sampling periods. Tukey's HSD test indicated three separate regimes – summer, fall, and winter-spring.

Predictive Relationships: Correlation Structure among Water Quality Parameters

The correlation coefficients among the stream water quality parameters are given in Table 9-7. As can be observed from this table, the most dominant correlations are between water temperature and DO (-0.84), water temperature and specific conductance (-0.33), turbidity and pH (0.31), specific conductance and DO (0.30), and specific conductance and pH (0.20). The eigenvalues are displayed in Table 9-8 and strongly indicate that there are two latent factors that explain 72.476 percent of the total variance.

Table 9-7. Correlation Coefficients among Stream Water Quality Parameters.

Parameter	DO	pH	Water Temperature	Specific Conductance	Turbidity
DO	1.00	-0.05	-0.84	0.30	0.10
pH	-0.05	1.00	0.08	0.20	0.31
Water Temperature	-0.84	0.08	1.00	-0.33	-0.08
Specific Conductance	0.30	0.20	-0.33	1.00	0.46
Turbidity	0.10	0.31	-0.08	0.46	1.00

Table 9-8. Eigenvalues Analysis for Water Quality Parameters.

Eigenvalue	Percent	Cumulative Percent
2.1334	42.676	42.676
1.4900	29.800	72.476
0.7286	14.573	87.049
0.4951	9.903	96.952
0.1524	3.048	100.000

Table 9-9 displays the associated eigenvectors and the principle factor solutions for the two latent variables. Factor-1 is heavily weighted with the parameters of dissolved oxygen and stream water temperature; Factor-2 is heavily weighed with pH and Turbidity. The results of the varimax rotation are given in Table 9-10 and indicate that Factor-1 was highly correlated with DO and water temperature and that Factor-2 was highly correlated with pH, specific conductance and turbidity.

Table 9-9. Factor Analysis for Water Quality Parameters: Principal Factor Solution.

	Factor-1	Factor-2
DO	**0.581**	-0.327
PH	0.101	**0.584**
Water Temperature	**-0.582**	0.346
Specific Conductance	0.467	0.339
Turbidity	0.309	**0.563**

Table 9-10. Factor Rotation: Varimax Factor Analysis.

	Factor-1	Factor-2
DO	**0.937**	0.038
PH	-0.198	**0.700**
Water Temperature	**-0.949**	-0.018
Specific Conductance	0.414	**0.682**
Turbidity	0.083	**0.819**

A preliminary examination of the two new latent variables, Factor -1 (DO-Water Temperature Index) and Factor-2 (Turbidity-Specific Conductance Index), was conducted through applying a stepwise regression. The data indicated that two predictive relationships among the latent variables and the meteorological variables could potentially be established. The model of choice for this predictive study was considered to be a dummy regression model in conjunction with the meteorological variables.

For both factors, the dummy variables in the model assumed values of 0 or 1 depending on whether or not the season was spring, summer, fall, or winter. The forward selection algorithm was used in the stepwise regression procedure in order to enter the meteorological variables that were most associated or which indicated the best predictive capabilities. For Factor-1 (the DO-Water Temperature index) all dummy variables were significant, indicating that a predictive relationship for each season was prevalent in the data. The important meteorological variables of interest were surface air temperature, relative humidity, wind speed, total precipitation, maximum solar radiation, and water depth. The regression coefficients, their respective standard errors, and the associated t-statistics are given in Table 9-11. As can be seen from this table, all coefficients were highly significant except for water depth, which was significant at the 0.0583 alpha level. The model given in Table 9-11 explained 84.83 percent of the total variation of the DO-Water Temperature Indexing Factor. An R^2 of this magnitude is a strong indicator that the predictive capabilities of the model are good. Thus, the conclusion of this analysis is that an apparent association between the dummy variables and the water meteorological variables listed in Table 9-12 and the DO-Water Temperature Indexing Factor (Factor-1) exists.

Table 9-11. Predictive Model: Factor 1 - DO-Water Temperature Indexing Factor.

Term	Estimate	Std. Error	T-Ratio	P-Value
Intercept	2.679	0.1996	13.42	< 0.0001
S1: Spring	-0.213	0.0881	-2.42	0.0158
S2: Summer	-0.719	0.1047	-6.87	< 0.0001
S3: Fall	-0.445	0.0761	-5.85	< 0.0001
Surface Air Temp	-0.064	0.0050	-12.77	< 0.0001
Relative Humidity	-0.010	0.0024	-4.20	< 0.0001
Wind Speed	0.062	0.0274	2.28	0.0233
Total Precipitation	0.008	0.0029	2.63	0.0089
Max. Solar Radiation	-0.001	0.0001	-6.96	< 0.0001
Depth	0.148	0.0778	1.90	0.0583

Table 9-12. Predictive Model: Factor 2-Turbidity – Specific Conductance Indexing Factor.

Term	Estimate	Std. Error	T-Ratio	P-Value
Intercept	51.8293	8.1904	6.33	< 0.0001
Barometric Pressure	-0.0507	0.0080	-6.30	< 0.0001
Wind Speed	-0.2156	0.0566	-3.81	0.0002
Total Precipitation	0.0175	0.0063	2.78	0.0057

For Factor-2 (the Turbidity-Specific Conductance factor), the dummy variables representing seasons were not significant, indicating that seasons were not a major factor in predicting turbidity and specific conductance. The important meteorological variables were barometric pressure, wind speed and total precipitation. The model described in Table 9-12 explained only 16.64 percent of the total variation, and the lack of significant seasonal effects indicate that Turbidity, Specific Conductance, and/or pH did not vary significantly with seasonal changes.

The small R^2 implies that the meteorological variables of barometric pressure, wind speed, and total precipitation are considered as weak predictors of the Turbidity – Specific Conductance Indexing Factor.

Ground water temperature varied with respect to seasons, surface air temperature, relative humidity, total precipitation, maximum solar radiation, and the distance from the top of the casing to the water's surface. Table 9-13 displays the regression coefficients of the models and their associated standard errors and the hypothesis tests associated with these parameters. The model explained 70.84 percent of the total variation, which is an indicator of the predictive capabilities of the parameters composing the model.

As is readily observed from Table 9-13 all seasonal dummy variables except for Summer (S2) were significant, thus, indicating that ground water temperature varied with seasons. Additionally, the meteorological variables of Surface Air Temperature, Relative Humidity, Total Precipitation, Maximum Solar Radiation, and the distance from the top of the casing (TOC) to the water surface serve as good predictors of ground water temperature.

Table 9-13. Predictive Relationship: Ground Water Temperature (Using Dummy Variables for Season)

Term	Estimate	Std. Error	T-Ratio	P-Value
Intercept	14.6212	0.1014	144.15	0.0000
S1: Spring	-1.0252	0.0388	-26.40	<0.0001
S2: Summer	-0.0121	0.0512	-0.24	0.8127
S3: Fall	1.2103	0.0371	32.66	<0.0001
Surface Air Temperature	-0.0134	0.0024	-5.59	<0.0001
Relative Humidity	0.0032	0.0011	2.92	0.0035
Total Precipitation	-0.0078	0.0015	-5.23	<0.0017
Maximum Solar Radiation	-0.0002	0.0001	-3.14	0.0017
TOC – Water	1.0999	0.0175	62.91	0.0000

The last model considered in this analysis was a study of stream turbidity during the seasons of winter and spring only. This subset of the data was studied in more detail as it was felt that winter and spring periods represented the wetter months of the year; and, thus, if a relationship existed for turbidity alone, this period of the study window should produce such an association. Table 9-14 displays the relationship for turbidity as a function of total precipitation, water depth and the interaction of these two parameters. As can be seen from Table 9-14, the predictor variables were significant; however, the model only explained 17.44 percent of the total variation. This low R^2 is a good indication that these parameters are weak predictors for turbidity.

Table 9-14. Predictive Relationship: Turbidity (Winter and Spring Data Only)

Term	Estimate	Std. Error	T-Ratio	P-Value
Intercept	21.5961	15.032	1.44	0.1522
Total Precipitation	6.1990	1.0955	5.66	< 0.0001
Water Depth	77.7804	29.8306	2.61	0.0097
(Tot_Prec – 3.756)(Depth – 0.426)	-9.0031	3.0538	-2.95	0.0035

Conclusion

The conclusions of this report stem from an analysis of data collected over a period of time beginning in 1999 and ending in 2004. The database was extremely large and covered a broad spectrum of parameters representing meteorological data, stream water quality data, and ground water data; and the analysis of this database forms the basis for data mining or outcomes research. The focus of the analysis was geared more toward exploration relationships rather than establishing relationships. The regression analysis models should be considered as associations rather than cause-effect models.

With these analyses as a basis, in 2006 we plan to add the 2005 and 2006 data to the data set and use the data set to accomplish the following tasks.

1. Correlate the meteorology data set from Fort Benning, 1999 – 2006, to the same period of record within the 100 + year data set from the Columbus, GA airport. We can then develop a correction factor that will allow an extrapolation of the Fort Benning data set to a 100 + year period with a known level of confidence.
2. Perform a power analysis procedure on all monitoring data sets (meteorology, surface and ground water) for the period 1999 – 2006 to determine the minimum level of sampling (frequency and number of locations) that will be required in the future to continue to monitor trends effectively.
3. For the water quality monitoring we plan to determine the fraction of the flow regime (hydrograph) that we are capturing with our current sampling regime. This information could then be used to justify the cost and effort to develop flow rating curves for the streams and to adjust our level of sampling to capture a larger, more meaningful portion of the flow regime.

The idea is to use what we have learned from the monitoring to adapt the monitoring scheme to better meet SEMP and installation needs for the future.

Technology Transition Plans / Land Cover Analysis

Plans have been developed to conduct a workshop during the second quarter of 2006 at Fort Benning, GA, for the Land Management Branch in support of the SEMP Monitoring and Research Infusion Technology Transition Plan. This initial workshop will be focused on transitioning the land cover analysis and classification techniques to the installation personnel.

Details regarding the outcome of this workshop will be provided in the 2006 report.

There is no one ideal classification of land use and land cover, and it is unlikely that one could ever be developed. There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is, in fact, no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change in keeping with demands for natural resources. Each classification is made to suit the needs of the user, and few users will be satisfied with an inventory that does not meet most of their needs. In attempting to develop a classification system for use with remote sensing techniques that will provide a framework to satisfy the needs of the majority of users, certain guidelines of criteria for evaluation must first be established. The following tasks outlined for the workshop are designed to provide the user with the general process of performing an image classification and land cover map. A user manual will be provided to participants and will contain the necessary details and guidance to perform each of the tasks.

Task 1: Preparing the Landsat image data.

Task 2: Performing the ISODATA Unsupervised Classification.

Task 3: Evaluating the spectral signatures.

Task 4: Performing the Supervised Classification.

Task 5: Refining the final product.

Task 6: Performing the accuracy assessment.

ERDAS Imagine Professional is the software that has been used to develop the land cover assessments since 1999. Therefore, to maintain continuity in the land cover analysis procedure a site license for the software will be purchased for the Fort Benning Land Management Branch prior to the workshop so they can become familiar with the software in advance. After the workshop we will determine if a follow-on workshop will be required to continue supporting the Fort Benning personnel during the technology transition process.

10 SEMP Integration Project Annual Report 2005

SERDP Ecosystem Management Project (effort within SI-1114)
Principal Investigator: Dr. Virginia H. Dale, Oak Ridge National Laboratory

Introduction and Background

The SERDP Ecosystem Management Project (SEMP) implemented three indicator studies and two threshold studies but had no formal plan for integration. SERDP funded this project in order to evaluate the data collected by those five components and begin to integrate them. The purpose of the integration was to focus the results of the research and monitoring programs on complementing Integrated Natural Resource Management Plan (INRMP) and improving environmental management of Fort Benning. Ultimately, the lessons learned at Fort Benning may provide an example of how to improve environmental monitoring and management of DOD installations in general. This work focused on indicators at the plot level. However, indicators at the watershed and landscape level were considered by the Technical Advisory Committee to be a part of integration. Work on this project was finished in 2005; however the report is expected to be completed in early calendar year 2006.

Accomplishments

We developed a framework for integrating and analyzing the data collected at Fort Benning by many researchers across the five teams. This retrospective analysis required an uncommon approach for the selection of indicators that best discriminated land-management categories. There were two key components to this work, (1) the development of land-management categories and (2) variable screening by multiple solutions. Although the data for this effort was not collected in a fashion commensurate with traditional statistical techniques, it was still possible to integrate the separate research efforts and score the results. The use of selection scores provided a straightforward comparison of each indicator and this was important in obtaining results.

We first developed a land-management category (LMC) matrix, which provides a means of identifying areas on the base discretely according to the land-management goal for the area, the military activity that occurs in the area, and the frequency of that activity. Criteria for indicator selection were finalized through discussions with the research teams and with Fort Benning resource managers. Evaluation criteria were divided into two groups: those based on technical effectiveness and those based on practical utility. Discussions with the Fort Benning resource managers were important to determining the criteria for practical utility.

Data from the individual indicator projects were collected from the research teams, and statistical analysis is complete. A clear and readable list of the indicators at the site, watershed, and landscape scale of resolution was prepared and has been distributed to the Technical Advisory Committee and Fort Benning resource managers. Conceptual models were developed that show how the indicators vary across time and space. These models also reflect great variation in the indicators across the biological hierarchy. A report was prepared that shows how the approach relates to the alliance vegetation layer prepared by The Nature Conservancy at Fort Benning.

A plan to map the land-management categories at Fort Benning was developed and approved in August 2004. Work on the mapping effort was completed and involved significant discussion with the resource managers at Fort Benning (both from the military and The Nature Conservancy).

The LMCs were mapped in order to provide a spatial interpretation of the categories developed. Two maps were made for this effort. The first map illustrates the land management goals and endpoints and was created using data from different sources including the 2001 landcover, forest inventory data from Fort Benning, and a vegetation map from The Nature Conservancy . Three main categories were included in this map – minimally managed areas, areas managed to restore or preserve upland forests, and areas managed to maintain an altered ecosystem. Discussions with Fort Benning staff helped in uniquely assigning areas to these categories. The second map documents the cause of predominant ecological effect from military use of land. Different military training activities, such as using tracked or wheeled vehicles, firing ranges etc. are mapped with respect to the area they are allowed to occur on. Information on training activities and their restrictions were obtained from Fort Benning personnel and the Fort Benning environmental awareness training guidelines.

Major Findings

- A collective vision for the land can be derived among resource managers with diverse objectives if care is taken to be sure that terms are communicated clearly and if all stakeholders have the opportunity to participate in discussions.
- Land-management categories can be developed based on the management goal for each area, the use of the land, and the frequency of that use. These land-management categories provide a meaningful way to resource managers to formalize their goals for the land given expected uses and to identify indicators that can be used to monitor if each goal is on track.
- Multivariate analysis supports our hypothesis that ecological indicators should come from a suite of spatial and temporal scales and environmental assets.
- Maps can be created that depict land management categories that cover both ecological interests and military land uses.
- Key indicators at the plot levels include:
  - Soil physical and chemical variables: soil “A” horizon depth, compaction, organic matter, organic layer N, NH3, Total N, N mineralization rate, Total Carbon and % Carbon.
  - Soil microbiological indicators: biomarkers for fungi, Gram-negative Eubacteria, soil microbial respiration and beta-glucosidase activity.
  - Plant family and life form indicators: the Family Leguminosae, possibly Rosaceae, and the plant Life forms Therophyte, Cyptophyte, Hemicryptophyte and Chamaephyte as well as understory cover, overstory cover and tree stand characteristics.
- Key indicators at the watershed level are:
  - Disturbance intensity
    - % bare area on slopes > 3%
    - % road coverage
  - Dissolved organic carbon and pH
  - Stream physical habitat
    - -- Coarse woody debris (CWD), BPOM, and flashiness: good indicators and best explained by contemporary land use
    - -- Stability: weak indicator, explained by historic land use

- Macroinvertebrates
  - --EPT (Number of taxa of the insect orders Ephemeroptera, Plecoptera or Tricoptera): good indicator, explained by historic land use.
  - --Chironomidae richness and GASCI: strong indicators and no legacy effect.
- Fish
  - -- Assemblage metrics: poor indicators, related to historic land use.
  - -- Population metrics: good indicators, both sensitive and tolerant populations related to contemporary land use.

- Key indicators at the landscape level are:
  - Percent cover of cover types
  - Total edge (with border) of patches
  - Number of patches
  - Mean patch area
  - Patch area range
  - Coefficient of variation of patch area
  - Perimeter to area ratio of patches
  - Euclidean nearest neighbor distance of patches
  - Clumpiness of patches.

Benefits

The project identified a suite of indicators that Fort Benning resource managers can use to make judgments about the ecological condition of the installation. Specifically, the resource managers have noted that indicators will be useful for planning budgets, providing a “heads up” regarding compliance with environmental legislation, signaling whether the installation is on the right path toward achieving longer term goals, signaling whether the installation is on the right path to achieve shorter term objectives, and suggesting the need for targeted projects and research. SERDP’s Science Advisory Board (SAB) sees the approach set forth by this project as an effective framework to integrate the indicators so they relate to the needs of the land managers.

The approach of developing and mapping land-management categories should be useful for other locations. It provides a means for communication across the various uses of the land, a format for collecting and interpreting monitoring data, and a framework for designing and implementing management goal.

The specific indicators identified at Fort Benning are likely to be of great importance for other military installations in the southeast. The categories of important indicators are likely to important in all locations. The approach for analysis of indicators should be generally transferable.

Challenges and Concerns

Because the integration project was initiated after the individual teams had designed and largely carried out their experiments, harmonizing the data into a format conducive to statistical analysis across all research teams has been challenging. The data were also restricted to those LMCs and structural, compositional, and functional features the research teams measured. Not all LMCs were sampled. The multivariate analysis was complicated by the diverse sampling approaches of the research teams. Even within some teams, the data on different indicators were collected in different places and/or at different times. Thus the focus of the analysis is on indicators as predictors of the LMCs. Because we did not have access to the data collected for the site condition index, the analysis is not as complete as it might otherwise be.

Data limitations required a new approach to integrating disparate data from several research teams at Fort Benning. Since the ecological indicator information was spread over several data sets, a way had to be established to integrate and compile the results. The approach of multiple solutions with scoring allowed us to compare the fitness of each indicator for the prediction of LMCs without the limitations of other more traditional statistical methods. The results and insights gained from this effort appear to be consistent with other work in ecological indicators.

11 Knowledge Management and Data Repository

Dr. Chris Rewerts, U.S. Army ERDC-CERL

Background

As SEMP research has progressed and the program matures, the data repository has been undergoing transition to better serve SEMP, the research and Fort Benning community, as well as the larger community. The need for these changes were highlighted by discussions of how to improve technical transfer from SEMP to stakeholders in SERDP and SEMP meetings as well as in the report prepared by the Rand Corporation in 2004. Therefore the work previously described as the “SEMP Data Repository” is now “SEMP Knowledge Management.” reflecting a change from collecting data to a vision of Ecosystem Knowledge Mapping.

Ecosystem Knowledge Management asks the following questions:

- How can we make scientific knowledge and data (such as the outcome of SEMP projects and their data) more readily usable by natural resource managers who could benefit from the knowledge to make decisions?
- How can we better enable our researchers to communicate, collaborate, and contribute to our collective scientific knowledgebase?
- How can we better organize and represent the goals and drivers of natural resource managers so we can better target our research on their needs?
- How can tools we use to facilitate collaboration and communication also capture content that will help document how and why decisions were made?

The SEMP Knowledge Management Project has endeavored to improve the data repository by taking initial steps toward the vision of Ecosystem Knowledge Management in a practical and pragmatic way.

Focus Areas

In 2005 the SEMP Knowledge Management Project has made accomplishments in the following areas (each will be discussed further in the following sections):

- Website foundation and framework – a secondary, developmental website was established to enable the construction and testing of a re-designed portal while keeping the current SEMP Data Repository (SDR) functional.
- Implementation of the Open Archives Initiative Protocol for Metadata Harvesting (http://www.openarchives.org/) and experimentation with the SRU subset of the Search/Retrieve for Web Services protocols.
- Design and population of a library database for SEMP documents.
- Research and collaboration with other groups working in similar domains.

Website Foundation and Framework

A second website was established as a developmental/beta test location for redesign of the data repository so the current site could remain usable during development and testing of the new site. The new site was established through formal registration and review as a website with the DoD and Army. Both sites are hosted on the same server, hosted by the ERDC Web farm (http://itl.erdc.usace.army.mil/webfarm/index.html). The redesigned site is upgrading the foundational elements supporting the current site, enhancing security and complexity of administration of users and data objects, upgrading the underlying database, and adding web portal functionality. For technical reasons both sites were moved in late 2006 to http://semp.cecer.army.mil (or http://sempdata.cecer.army.mil) so that final develppment could be completed.

Every website has foundational elements, such as the web server software and accompanying architecture for development of web pages and connections. The web server software remains Microsoft's Internet Information Service (IIS). The primary function of the SDR is focused on data; therefore the site requires programming tools to create dynamic page presentation and interaction with the user. As with the current SDR site, the developmental is using Microsoft's ASP.NET framework. However, the new site began using the beta 2.0 version of ASP.NET because of the greatly enhanced compliance with html standards, increased functionality for data presentation and dynamic interaction, and better ability to separate business logic from the presentation layer. The current SDR site's database engine is Microsoft Access, which is being upgraded to Microsoft SQL Server for the new site to increase capacity, security, and functionality.

On top of the foundation, the redesign of the SDR requires the addition of more website functionality, increased security, granularity of user roles and management, and ability to expand to support multiple repositories (enabling potentially adding additional parallel repositories for new SERDP programs similar to SEMP). Thus the developmental site needed a framework for a data-driven internet portal that provides the following types of functionality:

- Ability to host multiple sub-websites/portals from a single database.
- User administration and roles tools for account management.
- Access security roles and protected content control for any given page or subpage.
- Customizable appearance.
- Site logging tools.
- Bulk email capabilities.
- Ability for user-created web pages.
- Advanced data query and display capability.

This functionality is currently being enabled and tested on the developmental website.

Implementation of the Open Archives Initiative Protocol for Metadata Harvesting

SEMP Knowledge Management began collaborating with the University of Illinois Graduate School of Library and Information Sciences to explore technologies and protocols to increase the capacity for access to and duration of the SDR holdings. This resulted in a project to implement the Open Archives Initiative (OAI) Protocol for Metadata Harvesting (PMH) for the SDR. The OAI-PMH is method to make selected metadata records available more widely through third-party OAI metadata harvesting services managed by libraries, clearinghouses, and other information aggregators. The NSF-Sponsored National Science Digital Library (http://www.nsdl.org) is an example of an online digital library that uses a federated search of indexes harvested from other libraries, websites, and online data sources. The following text from the Open Archives Forum online tutorial provides a concise description of the OAI protocol:

> The OAI-Protocol for Metadata Harvesting (OAI-PMH) defines a mechanism for harvesting records containing metadata from repositories. The OAI-PMH gives a simple technical option for data providers to make their metadata available to services, based on the open standards HTTP (Hypertext Transport Protocol) and XML (Extensible Markup Language). The metadata that is harvested may be in any format that is agreed by a community (or by any discrete set of data and service providers), although unqualified Dublin Core is specified to provide a basic level of interoperability. Thus, metadata from many sources can be gathered together in one database, and services can be provided based on this centrally harvested, or "aggregated" data. The link between this metadata and the related content is not defined by the OAI protocol. It is important to realise that OAI-PMH does not provide a search across these data, it simply makes it possible to bring the data together in one place. In order to provide services, the harvesting approach must be combined with other mechanisms.
> OAI, http://www.oaforum.org/tutorial/english/page1.htm

The use of the OAI-PMH is an important avenue for the SDR to explore, since it not only can provide a means to share data with a wider community, but also can enable sharing data in fashion that makes the SDR metadata more computable, raising the ability for data availability well beyond the SDR web interface.

The project produced a working implementation of the OAI-PHM Data Provider for the SDR that will serve as an increment of what should be a more fully implemented version when the redesigned SDR is more fully functioning. The project provided a number of important lessons of what the redesign needs to address as well. The two most important areas for improvement found by this project related to how SDR holdings are indexed and accessed. To make the SDR more valuable as a node of scholarly communication, and to make the SDR holdings more accessible and useful to the wider community, the descriptive index information held in the SDR database needs to be improved to be richer, more granular, and compliant with standard vocabularies. Secondly, the SDR needs to improve the way the actual files or objects of the SDR holdings are referenced. Currently, since the web interface provides the access to the file, the index simply contains a URL link to the file. However, for a method such as OAI-PMH, this needs to be better abstracted so that the metadata can be harvested or shared, searched, and viewed by others, with functions for negotiating actual data access being handled in a more sophisticated way. For example, a scientist may discover SDR data by searching a remote library or clearinghouse that has harvested SDR metadata, and thus be led to the SDR. The given SDR holding may or may not be available for public access. There is currently no functionality to provide access to public data, nor is there more than the most rudimentary ways to contact the owner of the holding to make inquiries.

A full final technical report of the implementation of the OAI-PHM metadata provider for the SDR is available.[1]

Design and Population of a Library Database for SEMP Documents

As SEMP Project Management began to formally reorganize their collection of SEMP-related documents, such as presentations, reports, technical reports, and journal articles, it became obvious that the SDR needed the addition of a document library. This was initiated before implementation of the redesign of the SDR website was far enough along to facilitate the library. An intermediate stand-alone database application was rapidly created so that collecting, organizing, and indexing the documents could be underway while redesign of the SDR was being implemented in parallel. The form and schema of the stand-alone document library was created so that it could later be merged with the rest of the SDR. Thus, the library consists of a database that holds index information about the holdings, in this case, document files, with links to the files themselves that are stored on the local computer file system.

The document library's primary database tables were organized into documents, people, projects, and institutions. The documents table contains information to index the primary information about the document, such as title, primary author, additional authors, and date. Authors are linked to entries in the table of people. Documents are also classified by a confined list of document types, such as special, administrative, monthly, annual, or in-process review and final project reports; journal articles;

[1] Timothy W. Cole. 2006. "Final Technical Performance Report: Implementation of the OAI-PMH Metadata Provider for the SEMP Data Repository". UNNV-CESU contract W9132T-04-2-0008. 33p.

professional society presentations; workshop presentation and reports; and so forth. A meetings table was created so that documents could be organized by meetings where they were presented, including the meeting planning agenda and reports. A document attribute was created to create a restriction on documents that are not to be shared with the public.

A project table was created to record information about SEMP and other related research projects, such as related projects funded by Fort Benning. Index information for documents can also link them to the project for which they were created. Project table data include links to the people table for the principal investigator, research team, and sponsor point of contact.

The people table contains the individual's contact information, including the institution for which they work. Institution information is contained in a table of the same name.

The schema of the document database provides a rich variety of ways to query documents, not only by the attribute combinations of document type, title, author(s), and date, but also by project and performing institutions.

Approximately 500 documents have been collected and indexed in the SEMP document library. Table 11-1 provides a breakdown of the numbers of document types and date. The next primary task will be the merging of the database and documents with the redesigned SDR to make the document library available on the web.

Table 11-1. SEMP Documents Indexed in Database as of July 2005.

Document Type	Document Date							Totals
	1999	2000	2001	2002	2003	2004	2005	
Monthy HSC Report	0	0	9	12	12	12	7	52
Fact Sheets	0	0	7	8	0	8	1	24
TTAWG/TAC/IPR/SAB Briefs	5	5	14	19	21	15	7	86
Annual Reports	0	6	14	11	8	1	2	42
Technical Reports	0	1	7	9	0	10	2	29
Project Summary	0	0	1	0	12	16	7	36
Quarterly Report	0	15	27	22	23	18	0	105
Management Plans	0	3	12	12	10	20	5	62
Theses and Dissertations	0	1	2	3	2	2	0	10
Prof. Society Presentations	1	3	4	10	24	8	10	60
Journal Articles	0	0	2	4	3	5	5	19
Totals	6	34	99	110	115	115	46	525

Research and Collaboration with Other Groups

The SEMP Knowledge Management Project interacted with a number of groups to engage stakeholders, to explore technologies or potential collaborations, and to participate in in-kind efforts. The following are highlights.

Geospatial

Interest has been expressed in a number of ways to provide better geospatial integration in the SDR. Meetings were conducted with Fort Benning GIS and other personnel to solicit ideas and suggestions of how to make the repository more useful to the installation, especially with respect to geospatial data and resources. A teleconference was also held with GIS representatives from Army Headquarters (HQDA), Regional Installation Management Agency, and Fort Benning to discuss the new Army Regulation in draft for Installation Geospatial Information and Services. These regulations will likely impact how GIS data can be shared or distributed by the SDR. At the current time, it was implied that installation GIS data should be available only through the HQDA GIS-R (Army GIS Repository) portal (https://gis.hqda.pentagon.mil), which is under construction. Because of the uncertainty of both the outcome of the final Army Regulation pertaining to GIS as well as the future functionality of the GIS-R, it became prudent to reprioritize planning and design for geospatial data handling and use for the SDR to a later period in time.

Metadata and Ecoinformatics

SEMP Knowledge Management participated in a workshop sponsored by the National Center for Ecological Synthesis and Analysis (NCEAS). The workshop provided information and hands-on experience with ecoinformatics tools created under the Knowledge Network for Biocomplexity Project (KNB) for the Science Environment for Ecological Knowledge (SEEK). Central to the workshop was learning about the Ecological Metadata Language (EML), which is their design for an ecological metadata standard. Because this standard is based on the same core metadata types used as the basis for the SDR indexes and metadata, it could provide a logical way to enrich the SDR metadata. Also presented was “Morpho,” a tool developed for researchers to develop EML metadata and project documentation. Morpho in turn is designed to publish EML metadata to Metacat, a web-based database to facilitate storage, query, and distribution of EML metadata between Metacat nodes.

At this time SEMP Knowledge Management recommends the adaptation and use of the EML and its tools to provide a path and tools to improve the creation, storage, and distribution of metadata of SEMP research and other related data.

12 Host Site Coordinator 2005 Annual Report

Hugh M. Westbury, University of Georgia - SREL

Introduction

In order to facilitate ecosystems research at Fort Benning, the most active training facility in the Army, SEMP established the position of Host Site Coordinator (HSC). The HSC is responsible for the safe conduct of field research and ensuring that research activities did not impact the installation's training mission. This task requires coordination with military operations personnel; compliance with installation procedures; logistic support in the form of vehicles, radios, and required training; and the maintenance of an attitude among the field crews that ensures safe and responsible conduct.

The Host Site Coordinator provides monthly reports on field research activity at Fort Benning and maintains an up-to-date GIS layer of all sample sites. These actions enable coordination of field studies between research projects and between the researchers and Fort Benning personnel.

At the conclusion of FY05, the SEMP HSC has facilitated over 3000 field trips into the Fort Benning training area without a serious accident and without interfering with military training. In FY05, SEMP, SERDP, and associated other researchers conducted 436 field trips that required over 1200 training compartment reservations and 227 co-location agreements with military training units (Table 12-1).

The coordination provided by the HSC was quickly appreciated as a management infrastructure that would also support field research by other organizations that were not SERDP-funded, but provided basic environmental data and research directly supporting the Army mission. These research activities include investigations of gopher tortoises, song birds, and stream sediment, and environmental assessment of the effects of major range construction projects. The installation funds a portion of the HSC to support this work.

After 6 years of research activity at Fort Benning, SEMP has clearly demonstrated that ecological research can be safely conducted at a military installation without interfering with the national defense mission. SEMP research has greatly expanded the baseline knowledge of the ecology of Fort Benning and the southeastern fall line/sand hill ecoregion. SEMP has provided useful information to the installation in support of regulatory requirements and has made progress in addressing the issues of Ecosystems Management that are characteristic of multi-scale, multi-discipline and multi-project research.

Table 12-1. Total Field Effort Coordinated by the Host Site Coordinator at Fort Benning, FY2000-2006 (number of field days). FY2006 data is projected.

Project Id	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006
ECMI (SI1114)	10	40	45	30	16	8	20
UFLG (SI 1114a)	92	66	99	108	139		
Prescott (SI 1114b)	49	49	47	38	3		
ORNL1 (SI 1114c)	25	28	67	62	5	5	
ORNL2 (SI 1114d)	6	5	2	3	0	8	
SREL1 (SI 1114e)	66	157	197	176	121	13	
TOTAL SEMP	**248**	**345**	**457**	**417**	**284**	**34**	**20**
ORNL3 (SI 1186)		25	44	94	167	110	58
SREL2 (SI 1302)				52	31	25	
ORNL3 (DMPRC)						22	15
TOTAL SERDP		**25**	**44**	**146**	**198**	**157**	**58**
GOPHER		120	1	127	152	133	
IBP					116	101	98
SEDMON						11	9
BRAC EIS							329
TOTAL OTHER		**120**	**1**	**127**	**268**	**245**	**437**
TOTAL FIELDWORK	**248**	**370**	**502**	**690**	**750**	**436**	**565**

Environmental Research FY00 – FY05

Figure 12-1 presents the number of field days in each year of the SEMP. A field day is one crew going into the training area for one day – there can be more than one field crew and field day on a given calendar day. Each field day represents an average of three training compartment reservations, one in four of which will require an agreement with military training units to share the compartment. Data for FY2000 includes 4 days that were accomplished in late September of FY99. Data for FY06 is projected.

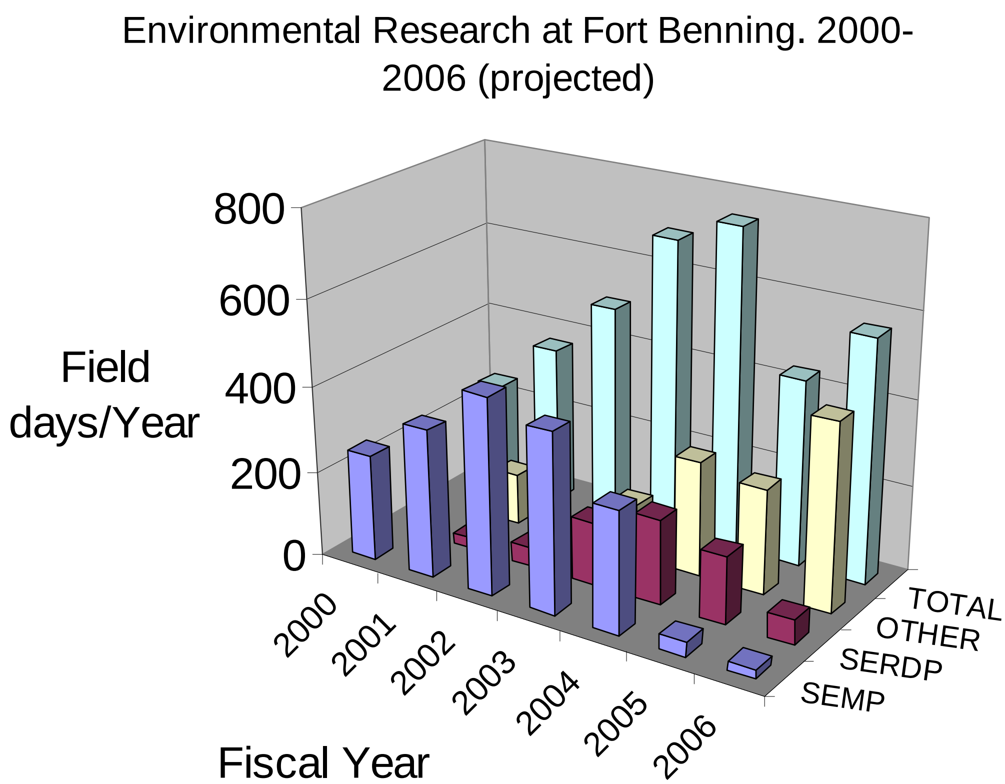


Figure 12-1. Environmental research at Fort Benning, 2000 - 2006 (projected).

Field work by the five ecosystems projects (SEMP) commenced in FY99 and peaked in FY02 with 457 field days. Of the original SEMP research effort, only the ECMI monitoring effort continues to conduct regular field trips. In fall, 2005, ORNL1, ORNL2, and SREL projects conducted the final field work of the two ecosystem SONs.

Additional projects (SI-1186, SI-1302), funded by SERDP but not part of the SEMP, commenced in FY01 and reached a maximum in FY04 of 198 field trips. The SERDP-funded Sand hills/TES project (SI-1302) concluded field work in April. The SERDP Riparian Project (SI-1186) will continue through FY2006, including additional funding to assess the effects of the construction of the DMPRC.

Field efforts coordinated by the HSC, but not funded by SERDP are shown as “Other.” These projects include gopher tortoise research funded by the Army and USFWS, avian winter survivorship surveys conducted by the Institute for Bird Populations (IBP) that is Army-funded, a stream TSS/turbidity study the is funded by Fort Benning, and several field studies funded by Fort Benning in support of the EIS for new ranges required by the additional training missions that were the result of Base Realignment and Closure (BRAC).

Over half (56 percent) of the field work coordinated by the HSC in FY05 was conducted for projects that were not funded by SERDP. In FY06, projected field research by non-SERDP research will account for 77 percent of the total effort. SERDP-funded research at Fort Benning has, for the past 2 years, focused on the development of environmental models and does not require significant field work.

DMPRC

In FY2004, clearing commenced for a new Digital Multi Purpose Range Complex (DMPRC). This large project requires the clearing of over 1100 acres and substantial earth moving activities. The DMPRC is located in the Bonham Creek and Sally Branch watersheds, which were the focus of much of the research conducted by SEMP. This project presents a unique opportunity to demonstrate the relevance of SEMP research, both in the utilization of data collected by SEMP and the actual application of monitoring techniques developed during the first 5 years of the project. Additionally, DMPRC provides a major disturbance that can be monitored to measure a wide suite of ecological consequences. In order to take advantage of the scientific opportunities afford by this large (>1100 acre) disturbance, CERL and Fort Benning have commenced additional monitoring and SERDP has funded an extension to the ORNL3 project.

Other HSC Activities

In addition to facilitating field research at Fort Benning, the HSC represented SEMP and provided displays at the installation's sustainability workshops in FY05. The HSC also attended the SERDP Partners in Progress conference in November 2004.

The HSC is also funded by ECMI to support environmental monitoring at Fort Benning. Among these activities, the HSC established and maintains a water quality monitoring station on Clear Creek to document preconstruction conditions and construction impacts for the installation's Clear Creek wetland restoration project. This project is a mediation requirement for the construction of DMPRC.

The HSC is also funded to support the TSS/turbidity study that is funded by Fort Benning and conducted jointly with ERDC. In FY05, the HSC secured research equipment from Fort Bragg and helped establish 8 new water quality monitoring stations and conducted routine sample collection and maintenance at these stations.

13 Technology Infusion Process

Don Imm, University of Georgia - SREL

The need for a technical liaison to integrate research findings into natural resource management planning and operations was identified early in FY05 following a series of workshops and meetings involving SERDP and SEMP staff, research partners, and Fort Benning environmental management staff. The position is dependent upon successful communication with and between research and natural resource management groups as well as a comprehensive understanding of the research findings and management initiatives. In general terms, the position duties would be focused on integrating research findings into developing land management and conservation plans and operational procedures as well as participate in defining future research needs and direction. The process of technical integration can involve (1) the concatenation of research findings to clarify, characterize, and assess new or immerging environmental problems (2) refine or identify monitoring needs associated with projects or program level activities (3) evaluate and compare of research techniques that may be used for monitoring, and (4) validate research findings through comprehensive literature review and additional field evaluations.

The technical liaison position was filled in April 05, when Dr. John Dilustro was hired through a contract with the University of Georgia-SREL. The employee was previously associated with an existing SEMP project; therefore he was already familiar with past initiatives at Fort Benning as well as the relevant staff associated with other the research and land management/conservation initiatives.

The initial focus (April through July 2005) was to accrue and update the available research reports, publications, and data associated with SEMP, SERDP, ECMI, and other funded research projects conducted at Fort Benning or in comparable settings. These tasks also involved checking and cross-validating the information within the data repository. During the period, the need for a regionwide, multi-partnered, SEMP-sponsored, fire conference was assessed whereby the focus would be on strategies for initiating burning regimes in areas with accumulated litter and fuels.

During the initial period, cooperative initiatives were established. These efforts included identifying that there was a need to establish and develop a comprehensive monitoring plan and monitoring report that was inclusive of environmental information collected by the land management and conservation branches, as well as their partners, with that collected from outside funded efforts such as ECMI, SERDP, SEMP, CERL, and other state- and federally-funded initiatives. Such a comprehensive annual monitoring report and periodically updated monitoring plan would be consistent with INRMP (Integrated Natural Resource Management Plan) initiatives and be useful to internal and external user groups. In addition to these needs, efforts were made to include SEMP participation in the development of the new INRMP; in particular, incorporating research findings into the development of desired future conditions (DFC) as well as monitoring tools to assess the state and condition of the environment, as well as to monitor progress toward DFC management initiatives.

During the 4th Quarter the fiscal year, Dr. Donald Imm replaced Dr. Dilustro as the technical liaison. Time was spent in transition and familiarization with the program. These activities included a period of familiarization with the SEMP program, progress to date, and interactions with relevant research and management personnel. To provide a better understanding of annual and final reports, field review and site visits to past and ongoing research were conducted for each of the research programs. Interaction with off-site program managers and partners included participation in the SERDP research presentations at the annual ESA meeting (Montreal).

During the 4th Quarter, an initial assessment of applicability of research techniques for use in monitoring was begun. This assessment considered time and cost investment per unit sample, applicability and relevance to perceived environmental issues, and statistical characteristics associated with the technique. These would include spatial and temporal repeatability, applicability, constancy, predictability, volatility, range of capacitance to a problem, and correlative relationship with other metrics. Further, similarity between techniques and resultant values were also addressed; for example, soil bulk density and soil compaction are correlated, therefore, compatibly interchangeable from a monitoring perspective. Another example of technical review and application toward monitoring concerns vegetation sampling. Because each study addressed slightly different questions, each study used different field sampling techniques with unique assumptions, statistical strengths, and inefficiencies in application. Consideration of these techniques as well as other standardized techniques (e.g., NCVS methodology) will ultimately result in the development of an improved, information-based monitoring program. These efforts have continued into the FY06 program.

Late in 2005, a flow-matrix was developed that associated SEMP research products, and those from other relevant projects, in a generalized manner, to installation habitats and management objectives. This precursor effort will serve two functions: first, to identify information and research gaps, and second, to aid in the development of a comprehensive monitoring plan that is linked to landscape condition and limitation as well as land management expectations. The generalized habitats used in the development of this matrix included: upland pine forest, upland mixed forest and woodland, wetland and riparian mixed forest, and open field. Metrics focused on biological interaction and habitat complexity appear to be more appropriate for less disturbed habitat settings, while metrics associated with physical conditions and biological persistence appear to be best suited for heavily disturbed conditions. Examples of measures of biological interaction include ant community composition and diversity and its relationship to disturbance (see Chapter 5– Dr. A. Krzysik). Another includes habitat assessments using (study PIs: Krzysik-Ch. 5, Dale- Ch. 6, Collins- Ch. 8) comparison of relative abundance of different plant life form groups in the understory such as annual grasses to perennial grasses, legumes to shrubs, and so on. The presence and abundance of different life forms and plant family groups could be used for monitoring as well as for the development of restoration QA/QC metrics associated with forest management goals.

Also, late in CY 2005 progress was made in converting SEMP and SERDP project data sets to common formats, with common units and IUPAC-accepted nomenclature. Ultimately, all project data will be coalesced and integrated with that acquired by other organizations such as The Nature Conservancy (TNC) and the Conservation Branch programs. Over the long term, these data will become integrated with other GIS-based data resources and repositories and will be useful for future research initiatives as well as the development of integrated management-based models.

In collaboration with TNC efforts in developing a revised INRMP, general SEMP findings and techniques were incorporated into the INRMP through discussions and shared authorship of chapters associated with project- and program-level monitoring of existing and future initiatives, adaptive management strategies, future research direction, and the definition and refinement of DFCs for Fort Benning. Newly developed DFCs focus on broadly defined ecosystems that are inclusive of specific targets associated with biotic and abiotic indicators (e.g., presence of particular species), generalized states and conditions (e.g., age structure, vertical structure), and the recovery of specific species (e.g., RCW population and habitat in longleaf pine woodlands). Though these DFCs are less specifically related to individual program areas (e.g., game species management), these newly defined DFCs provide better long-term guidance toward a sustainable and manageable condition. In addition to sharing authorship of those documents previously listed, discussions and review of other chapters (e.g., silviculture, fire, wildlife management, etc.) were also made and shared with editors and chapter authors. Participation in the development and review of INRMP documents maximizes the opportunity to apply past-funded research to the land management activities as well as the monitoring of environmental conditions and progress toward land management goals. In return, concepts and ideas associated with research needs and research direction are improved as information gaps and new environmental concerns are identified.

Because of the ecological complexity of soil nutrient dynamics, the interpretation of associated results, and applicability to land management concerns, an effort was begun to review SEMP and other outside literature to address the following question: "Which soil chemistry parameters, techniques, and sampling protocol are most appropriate for monitoring environmental issues at Fort Benning?" Quite simply, various metrics evaluating the state, condition, and rates of transition were evaluated by SEMP investigators. Therefore, an overall review of research papers associated with Carbon and Nitrogen analyses was necessary. These reviews are in lieu of a future assessment on the efficacy and cost effectiveness of using various soil N and C parameters as potential indicators for monitoring. After review of these publications and other reviews, four general comments can be made: (1) chemical cycling in heavily disturbed uplands at or near the threshold of biological function are poorly understood; (2) greater work is needed to understand the chemical cycle interactions (e.g., interaction of C cycle and N cycle) and the relative role of generalized biological groups (e.g., fungi, bacteria, root profiles, soil macrofauna, etc.); (3) trends in chemical transfer rates (e.g., nitrification) or regulating activity rates (e.g., nitrobacter activity rates) are strongly influenced dependent on other controlling processes; and (4) measures of nutrient pools and measure of transfer are highly variable over space and time, therefore spatially and temporally restricted. Based on this review, the most appropriate attributes for monitoring at intermediate scales are those that are either "overarching" or cumulative such as MOM (mixed organic material), percent organic N, and percent organic matter. However, many of the other techniques (e.g., microbial activity rates, microbial diversity) may have usefulness as a diagnostic test in areas with unique problems (e.g., sites with ineffective range grass establishment). When applied, these techniques as well as those already in the "tool box," will lead toward an improved understanding of environmental conditions. However, continued work in analysis and interconnection of monitored variables remains a critical need.

Part of the SEMP initiative for the technical liaison includes assistance and coordination with other related projects. Therefore, assistance in the analysis of Sharitz' SERDP sandhill project was provided toward the end of CY 2005. This includes the development of a predictive habitat suitability model for sandhill TES plant species found at Fort Benning. This analysis also includes an assessment (through bootstrapping) of the precision and accuracy of extrapolating measured soil parameters to expanded scales within a soil series and evaluating the light environment using GIS imagery. This project will result in two models. The first will be useful in identifying areas whose characteristics may be troublesome when attempting to apply traditional principles usually associated with longleaf pine ecosystem. The second model will be a probability-based model for 10 listed or at-risk plant species that are currently or may become species of management concern. These models will aid in resource planning and effective use of available resources towards general natural resource management initiatives. Continued involvement with this study and other research programs is paramount in avoiding redundancy in addressing research questions, and participation facilitates the nesting of results from various studies into more comprehensive understanding that can develop improved land management application and concepts of remaining research needs.

To provide an overview of the past funded research projects to the natural resource and environmental program managers, one-page reviews of the current 24 published papers were developed. These reviews generally consisted of one paragraph focused on the general science behind the research, a second paragraph summarizing the research findings, and the third paragraph focused on the applicability and meaning to management activities. Eighteen reviews were released; release of the remaining six is pending the publication of submitted papers. Roughly two-thirds of the published papers were focused on terrestrial disturbances; the remaining publications were associated with stream and watershed issues. During FY06 these efforts will continue as well as lead to the development of an overall review of each of the final reports and an assessment of their applicability to natural resource management activities. As part of this effort, individual techniques are being technically described as assessed from the standpoint of applicability, cost, and relevance to existing or expected environmental issues.

In the late summer and fall of 2005, assistance in SEMP program development was provided periodically through document review, quarterly visits and discussion, assistance in developing presentations, and collaboration with ongoing research initiatives. During FY05, the SEMP program was refocused to apply the initial findings toward the development of additional research at Fort Benning and elsewhere, as well as provide applicable research-based services and products to the supporting land managers.

Appendix A: Descriptive Statistics: Meteorological Profiles Associated With the Monitoring Program

The sections below describe the distributional properties of each of the above listed meteorological ecosystem profiles.

Surface Air Temperature

Figure 1 below displays an overlay plot showing daily minimum, daily maximum, and daily average temperatures during the sampling window. As can be seen from this graph, no abnormalities in the temperature regimes were noticed during this 4-year sampling period. Charts 1, 2 and 3, respectively, show the distributions using Tukey's Box plots of the daily minimum, maximum, and average temperature data by month. The maximum daily average temperature reached 33.12 °C; whereas the minimum daily average temperature was –6.60 °C. The average daily temperatures were centered about a mean temperature of 17.25 °C with a standard deviation of 7.63 °C. The inner quartile range (IQR) fell between the temperatures of 11.26 °C and 24.09 °C, the 1st and 3rd quartiles, respectively. Ninety-five (95) percent of the average daily temperatures fell between a low of 1.93°C and 27.57 °C. The minimum daily temperature regimes centered about a mean of 11.69 °C with a standard deviation of 8.39°C. The lowest minimum daily temperature was –12.60°C. Ninety-five (95) percent of the minimum daily temperatures ranged from a low of –4.5°C to 22.70°C. The maximum daily temperature regimes centered about a mean of24.20°C with a standard deviation of 7.42°C. The highest maximum daily temperature was observed to be 38.20°C. Ninety-five percent of the maximum daily temperatures ranged from 8.0°C to 34.50°C. Tables 1, 2 and 3 on the following pages summarize the descriptive statistics of these three surface air temperature parameters.

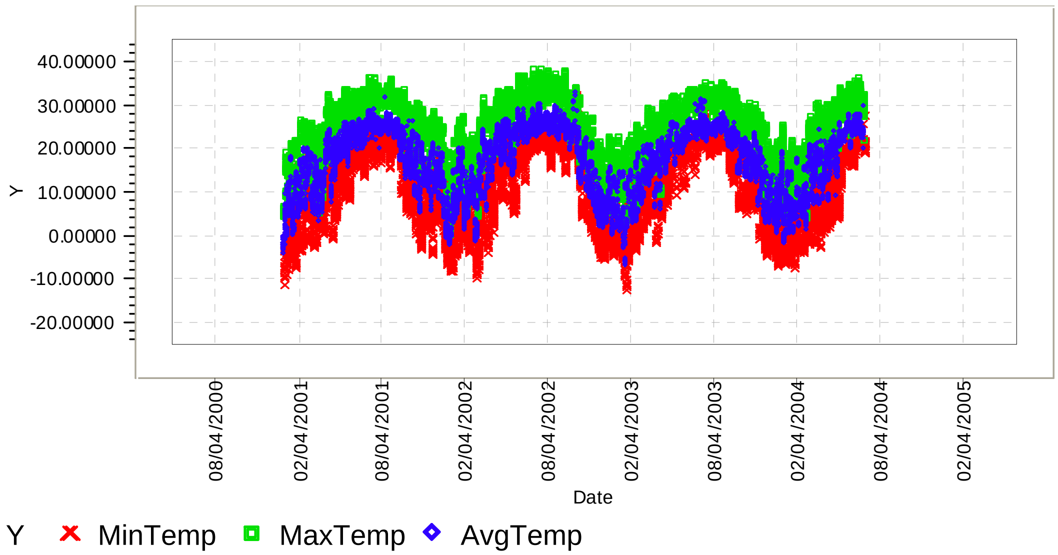


Figure 1. Average daily temperature distributions, 2001 – 2004.

Chart 1. Monthly Distributions of Daily Minimum Temperatures.

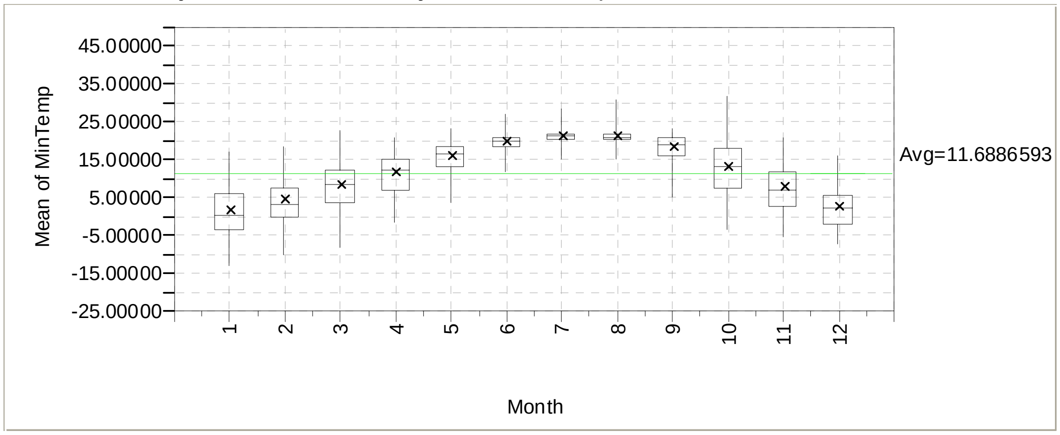


Table 1. Descriptive Statistics – Minimum Daily Temperatures.

Quantiles		
100.0%	Maximum	31.90
99.5%		23.90
97.5%		22.70
90.0%		21.50
75.0%	3rd Quartile	19.40
50.0%	Median	13.00
25.0%	1st Quartile	5.00
10.0%		-0.70
2.5%		-4.50
0.5%		-7.50
0.0%	Minimum	-12.60

Moments	
Mean	11.69
Std Dev	8.39
Std Err Mean	0.08
Upper 95% Mean	11.85
Lower 95% Mean	11.53
N	10,599

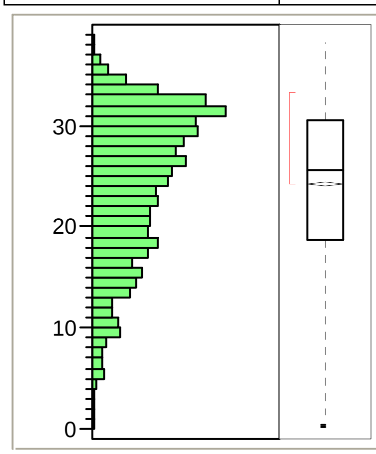


Chart 2. Monthly Distributions of Daily Maximum Temperatures.

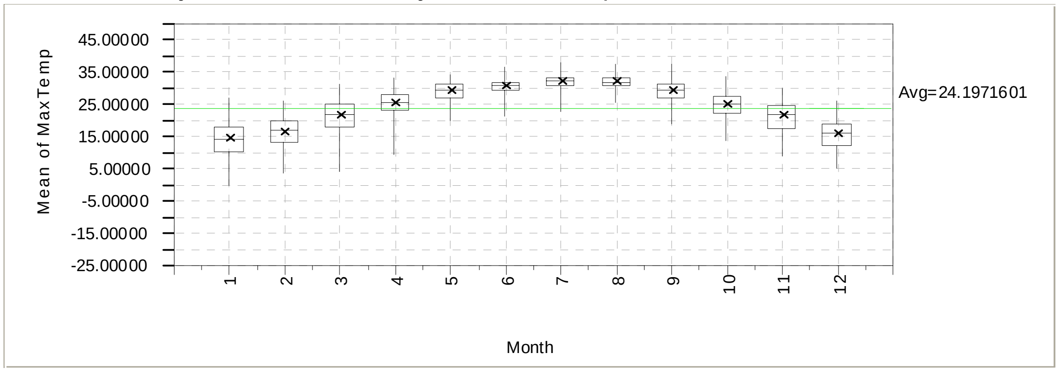


Table 2. Descriptive Statistics: Maximum Daily Temperatures.

Quantiles		
100.0%	Maximum	38.20
99.5%		36.30
97.5%		34.50
90.0%		32.60
75.0%	3rd Quartile	30.50
50.0%	Median	25.60
25.0%	1st Quartile	18.80
10.0%		13.60
2.5%		8.00
0.5%		5.00
0.0%	Minimum	0.20

Moments	
Mean	24.20
Std Dev	7.42
Std Err Mean	0.07
Upper 95% Mean	24.34
Lower 95% Mean	24.06
N	10,599

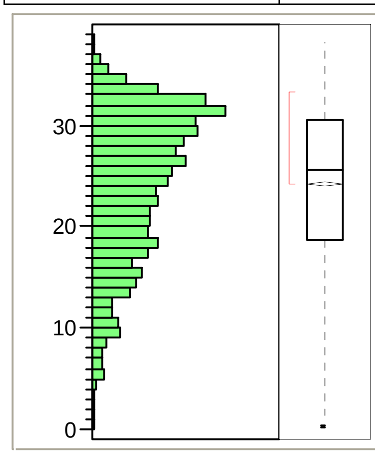


Chart 3. Monthly Distributions of Daily Average Temperatures.

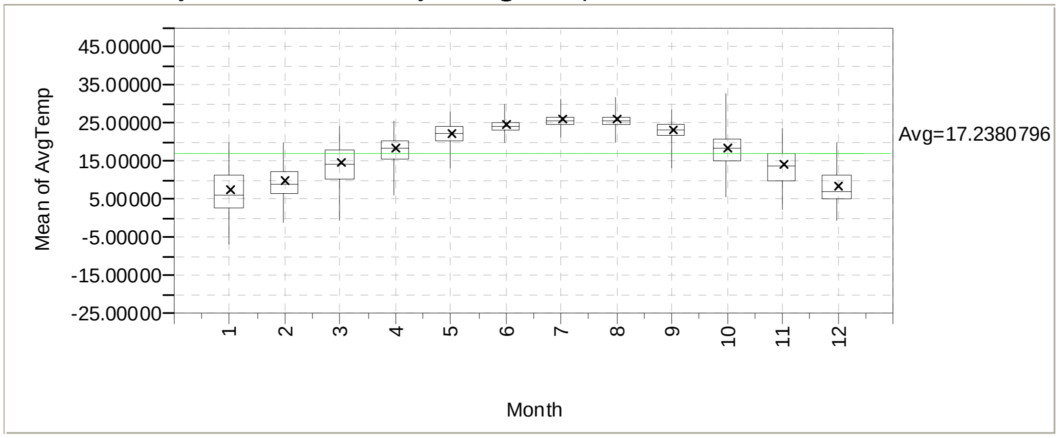
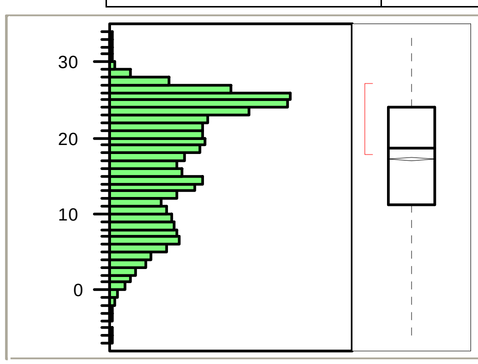


Table 3. Descriptive Statistics: Average Daily Temperatures.

Quantiles		
100.0%	Maximum	33.12
99.5%		29.01
97.5%		27.57
90.0%		25.94
75.0%	3rd Quartile	24.09
50.0%	Median	18.71
25.0%	1st Quartile	11.26
10.0%		6.00
2.5%		1.93
0.5%		-0.85
0.0%	Minimum	-6.60

Moments	
Mean	17.24
Std Dev	7.63
Std Err Mean	0.07
Upper 95% Mean	17.38
Lower 95% Mean	17.10
N	10,599



Average Daily Relative Humidity

The average daily relative humidity (RH) represented a highly skewed distribution. Fifty (50) percent of the RH data readings were above 72.52%. The minimum recorded RH was 19.81% and the maximum was 99.67%. In summary, 50% of the readings ranged between 72.52% and 99.67%; whereas, 50% of the data ranged between 19.81% and 72.52% on the low side. The daily average RH for the five-year study was 70.88% with a standard deviation of 13.17%. Chart 4 below displays the monthly distributions of the daily average RH data; the summary statistics describing these distributions are given in Table 4.

Chart 4. Average Daily Relative Humidity.

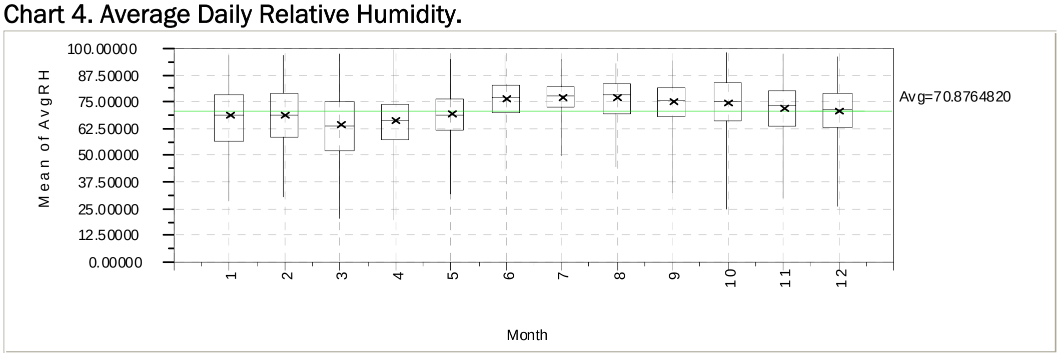
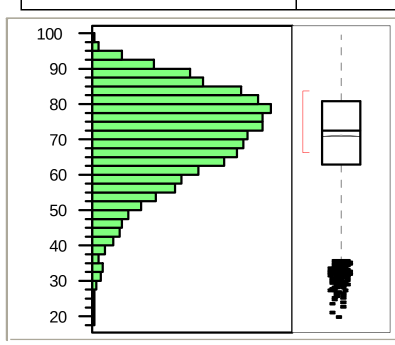


Table 4. Descriptive Statistics: Average Daily Relative Humidity Readings.

Quantiles		
100.0%	Maximum	99.67
99.5%		94.60
97.5%		91.50
90.0%		86.69
75.0%	3rd Quartile	80.73
50.0%	Median	72.52
25.0%	1st Quartile	62.71
10.0%		53.06
2.5%		40.96
0.5%		31.23
0.0%	Minimum	19.81

Moments	
Mean	70.88
Std Dev	13.17
Std Err Mean	0.13
Upper 95% Mean	71.13
Lower 95% Mean	70.63
N	10,599



Average Daily Barometric Pressure

Chart 5 displays the distribution of the average daily barometric pressure (BP) measures obtained during the four-year study. As can be seen from this Chart, the distributions are centered about 1018 mm Hg. Table 5 summarizes the data and shows the average daily barometric pressure values ranged from a minimum of 985 mm Hg to a maximum of 1038.1 mm of Hg. The histogram in Table 5 indicates a slight negative skew. Subsequent analysis yielded a skew of -0.516 with a kurtosis value of 0.716.

Chart 5. Average Daily Barometric Pressure.

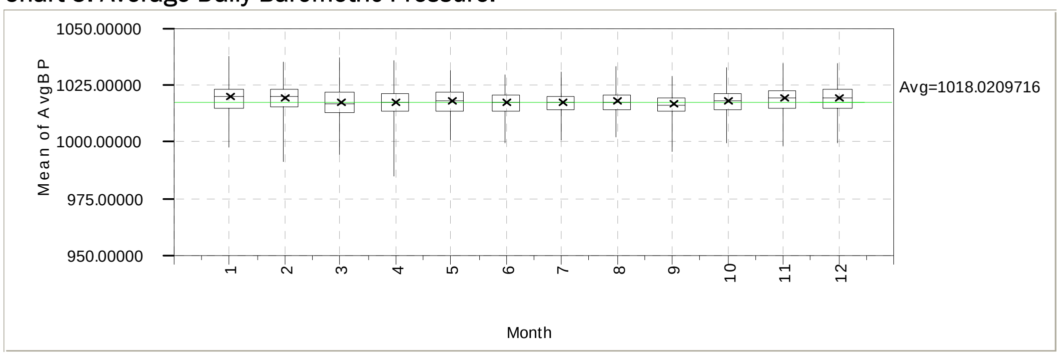
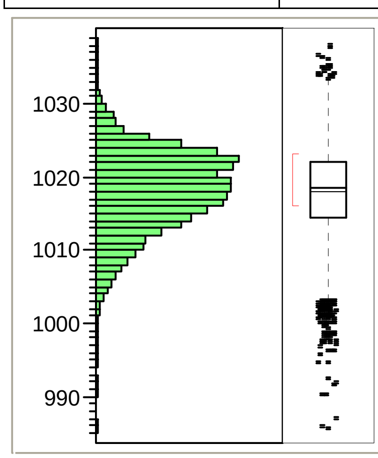


Table 5. Descriptive Statistics: Average Daily Barometric Pressure Readings

Quantiles		
100.0%	Maximum	1038.1
99.5%		1031.2
97.5%		1028.0
90.0%		1024.5
75.0%	3rd Quartile	1022.1
50.0%	Median	1018.5
25.0%	1st Quartile	1014.6
10.0%		1010.4
2.5%		1005.5
0.5%		1001.0
0.0%	Minimum	985.6

Moments	
Mean	1018.02
Std Dev	5.71
Std Err Mean	0.06
Upper 95% Mean	1018.13
Lower 95% Mean	1017.91
N	10.477



Maximum Daily Solar Radiation

As would be expected, two populations of maximum daily solar radiation (SR) were present in the measured data (see Chart 6). The two populations are indicative of SR values recorded during the periods of the year ranging from April through September and from October through March. The average daily SR value of all the composite data was 683.32 Watts/m^2. Thus, it appears that the maximum daily readings for the spring-summer periods were consistently above the average; whereas, the fall-winter period daily reading were consistently below the average.

Additionally, notice that the distribution as seen from the histogram appears to be a mixture of at least two populations.

Chart 6. Monthly Distributions of Daily Maximum Solar Radiation.

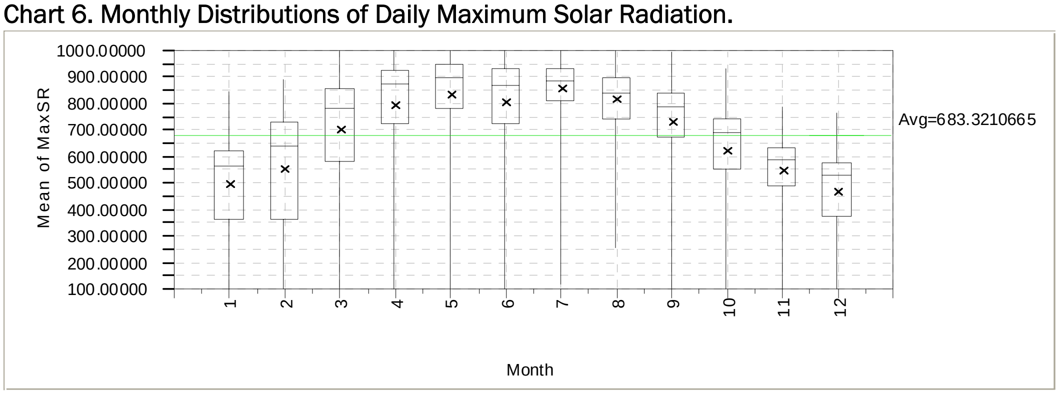
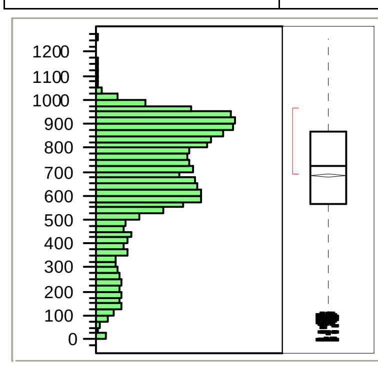


Table 6. Descriptive Statistics: Daily Maximum Solar Radiation Readings.

Quantiles		
100.0%	Maximum	1253.0
99.5%		1036.0
97.5%		986.0
90.0%		936.0
75.0%	3rd Quartile	870.0
50.0%	Median	722.0
25.0%	1st Quartile	565.0
10.0%		327.3
2.5%		138.0
0.5%		33.0
0.0%	Minimum	0.0

Moments	
Mean	683.32
Std Dev	230.36
Std Err Mean	2.23
Upper 95% Mean	687.70
Lower 95% Mean	678.95
N	10,652



Average Daily Wind Speed

During the study, the average daily wind speed ranged from a low of 0 to a maximum of 4.98 m/s. Overall, 99.5% of the wind speed data was less than 4.69 m/s. The average wind speed was 0.94 m/s with a standard deviation of 0.65 m/s yielding a coefficient of variation of 69%, which indicates the nature of the variability of wind speed data. Chart 7 below depicts the distribution of the wind speed data and Table 7 displays the summary statistics over the 4-year period.

Chart 7. Monthly Distributions of Average Daily Wind Speed.

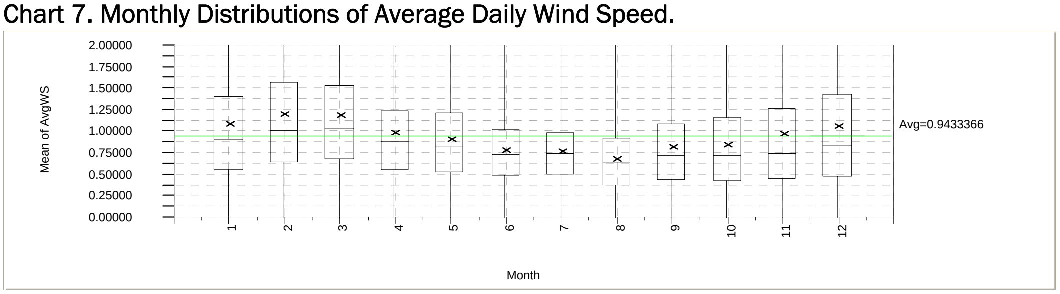
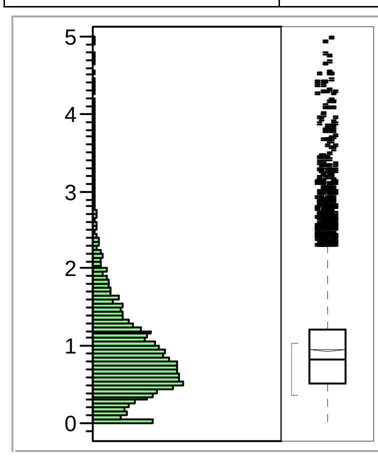


Table 7. Descriptive Statistics: Average Daily Wind Speed Readings.

Quantiles		
100.0%	Maximum	4.98
99.5%		3.69
97.5%		2.60
90.0%		1.76
75.0%	3st Quartile	1.23
50.0%	Median	0.81
25.0%	1st Quartile	0.51
10.0%		0.27
2.5%		0.03
0.5%		0.00
0.0%	Minimum	0.00

Moments	
Mean	0.94
Std Dev	0.65
Std Err Mean	0.01
Upper 95% Mean	0.96
Lower 95% Mean	0.93
N	10,652



Meteorological Data: Wind Direction

As would be expected, the directional data ranged from 0 degrees to 360 degrees, which indicates the variability of the wind direction. Fifty percent of the wind direction data fell between 107.32 Degrees North (first quartile) and 215.64 Degrees North (third quartile). This shows that the predominant wind direction varied ESE to SSW at an average speed of approximately 1 m/s. Chart 8 and Table 8 depict the distributional structure and the summary statistics for wind direction.

Chart 8. Average Daily Wind Direction.

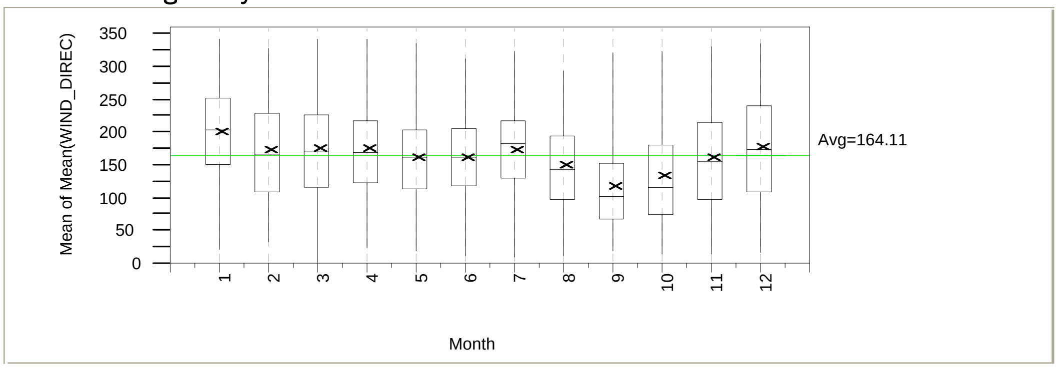
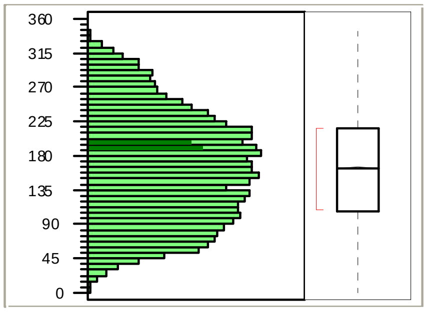


Table 8. Wind Direction Percentile/Quantile Statistics.

Quantiles		
100.0%	Maximum	343.19
99.5%		321.30
97.5%		302.50
90.0%		261.41
75.0%	3rd Quartile	215.64
50.0%	Median	162.80
25.0%	1st Quartile	107.32
10.0%		70.02
2.5%		44.73
0.5%		25.83
0.0%	Minimum	0.00

Moments	
Mean	164.11
Std Dev	70.76
Std Err Mean	0.69
Upper 95% Mean	165.45
Lower 95% Mean	162.76
N	10,652



Total Daily Precipitation

Total daily precipitation ranged from 0 mm to a maximum of 110.00 mm. Seventy-five percent of the total precipitation was less than 0.8 mm; whereas, 2.5% of the daily values exhibited significant amounts of rain fall in excess of 28.84 mm. The average total daily precipitation was 2.88 mm with a standard deviation of 8.38 mm. Chart 9 and Table 9 summarize the distributions of total daily precipitation.

Chart 9. Monthly Distributions of Daily Total Precipitation.

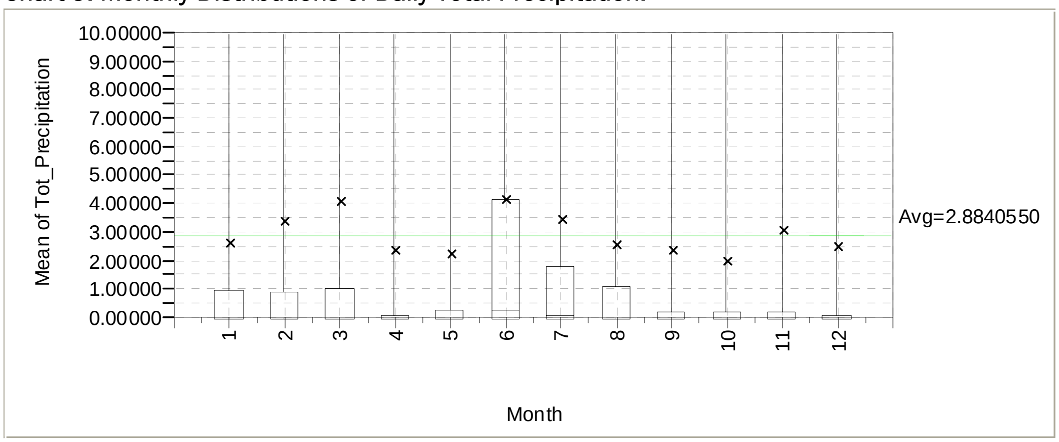
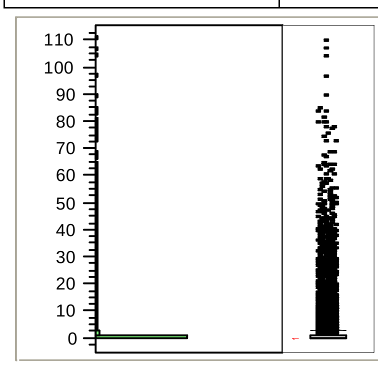


Table 9. Descriptive Statistics: Daily Total Precipitation Values (mm).

Quantiles		
100.0%	Maximum	110.00
99.5%		53.29
97.5%		28.94
90.0%		8.90
75.0%	3rd Quartile	0.78
50.0%	Median	0.00
25.0%	1st Quartile	0.00
10.0%		0.00
2.5%		0.00
0.5%		0.00
0.0%	minimum	0.00

Moments	
Mean	2.88
Std Dev	8.38
Std Err Mean	0.08
Upper 95% Mean	3.04
Lower 95% Mean	2.72
N	10,624



Stream Water Quality: Dissolved Oxygen

Dissolved Oxygen concentrations exhibited typical seasonal trends as measured at the five sampling stations located on Bonham Creek, Little Pine Knot, Oswichee Creek, Randall Creek, and Upatoi Creek. The highest levels of DO occurred during late fall and winter, and tended to decrease from March through July, which was followed by an increasing trend. Chart 10 displays the observed trends and represents a summary by month at the combined sampling stations. The yearly mean level of DO was centered about 8.59 mg/l with a standard deviation of 1.68. The distribution of DO did display a slight right skew. Table 10 below summarizes the descriptive statistics observed for the 4-year sampling window.

Chart 10. Monthly Distributions of Dissolved Oxygen.

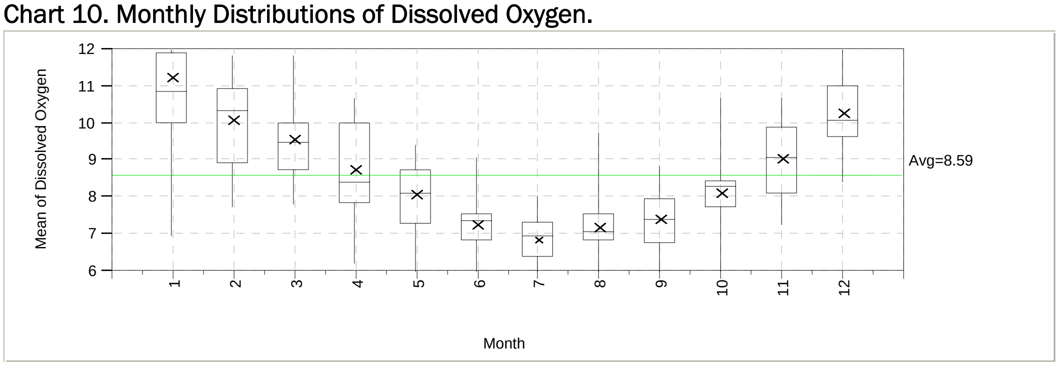
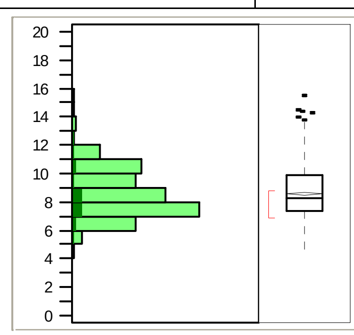


Table 10. Descriptive Statistics: Dissolved Oxygen.

Quantiles		
100.0%	Maximum	15.50
99.5%		14.45
97.5%		11.88
90.0%		10.77
75.0%	Quartile	9.89
50.0%	Median	8.28
25.0%	Quartile	7.35
10.0%		6.76
2.5%		5.96
0.5%		5.12
0.0%	Minimum	4.45

Moments	
Mean	8.59
Std Dev	1.68
Std Err Mean	0.07
Upper 95% Mean	8.73
Lower 95% Mean	8.45
N	575



Stream Water Quality: pH

The pH values observed during the sampling period centered about a mean of 4.95 with a standard deviation of 1.10. Chart 11 depicts the monthly distributional data and as is readily observed, there appears to be no apparent time-trends as was observed with dissolved oxygen. The data ranged between a minimum of 3.02 and a maximum of 8.33 with a median of 4.61. The histogram indicates a possible mixture, one centered on the median of 4.61 and another around 6.2. This could be reflective of differences among the streams, which will be addressed later in this report.

Chart 11. Monthly Distributions of pH.

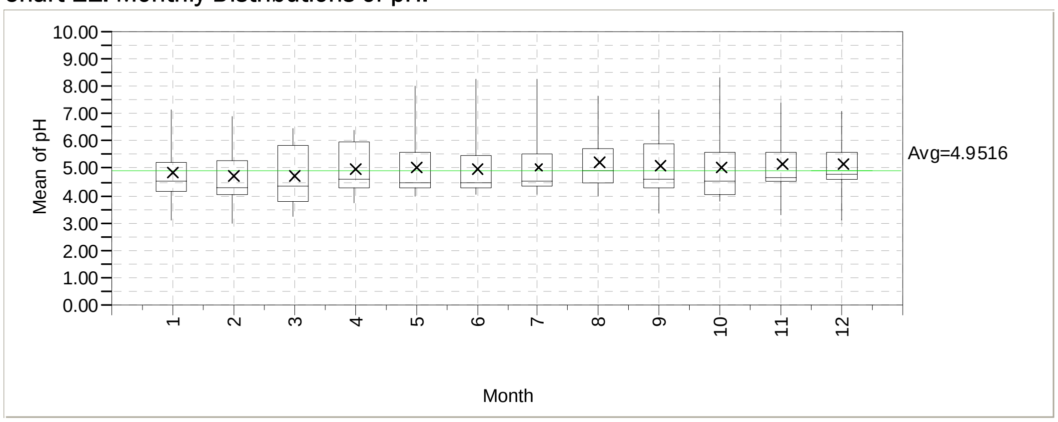
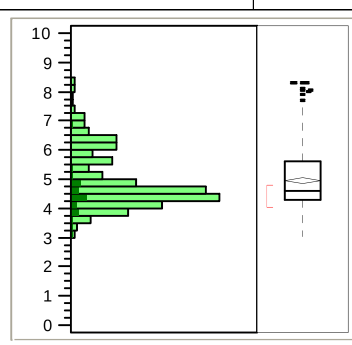


Table 11. Descriptive Statistics: pH.

Quantiles		
100.0%	Maximum	8.33
99.5%		8.30
97.5%		7.25
90.0%		6.41
75.0%	3rd Quartile	5.63
50.0%	Median	4.61
25.0%	1st Quartile	4.27
10.0%		3.98
2.5%		3.55
0.5%		3.14
0.0%	Minimum	3.02

Moments	
Mean	4.96
Std Dev	1.01
Std Err Mean	0.04
Upper 95% Mean	5.03
Lowerr 95% Mean	4.87
N	584



Stream Water Quality: Surface Water Temperature

Surface water temperature exhibited an opposite trend as compared to dissolved oxygen. The higher surface water temperatures occurred during the summer months, whereas the lower values were observed during the fall-winter-early spring months. The average yearly surface water temperature was 18.17°C with a standard deviation of 6.64. The temperatures ranged from a minimum of 2°C to a maximum of 36.4°C. The distribution tended to have a left skew, as would be expected with surface water temperatures. Ninety-five percent of the data ranged between 5.8°C and 28.83°C.

Chart 12. Monthly Distributions of Surface Water Temperature.

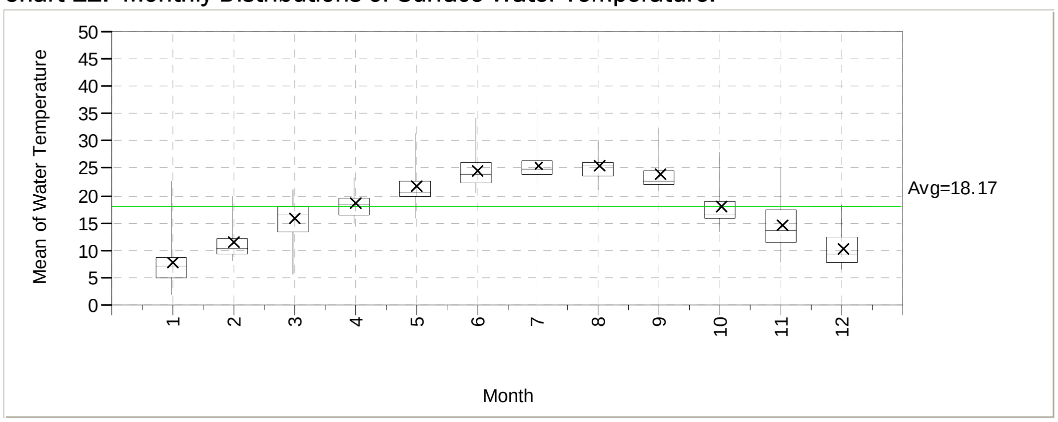
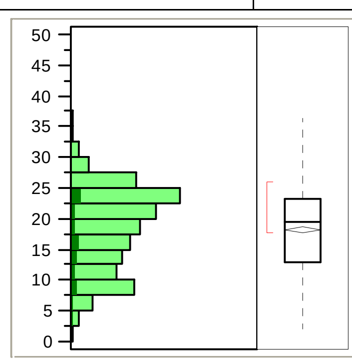


Table 12. Descriptive Statistics: Surface Water Temperatures.

Quantiles		
100.0%	Maximum	36.40
99.5%		32.46
97.5%		28.83
90.0%		26.10
75.0%	3rd Quartile	23.30
50.0%	Median	19.40
25.0%	1st Quartile	12.80
10.0%		8.60
2.5%		5.80
0.5%		3.14
0.0%	Minimum	2.00

Moments	
Mean	18.17
Std Dev	6.64
Std Err Mean	0.28
Upper 95% Mean	18.71
Lower 95% Mean	17.63
N	582



Stream Water Quality: Specific Conductance

Specific conductance tended to follow the same distributional pattern as dissolved oxygen with the higher recorded readings occurring during late-fall, winter, and early spring months and the lower recorded readings during mid-summer. The distributions tended to be more variable during the late-fall, winter, and early spring months than those observed during mid-summer. The mean specific conductance was 11.00 °S with a standard deviation of 15.48 °S. The coefficient of variation for specific conductance, thus, was 140.72%, which is an indication that the data is highly variable and not tightly coupled about the mean. The histogram given in Table 13 also shows a highly skewed distribution.

Chart 13. Monthly Distributions of Stream Specific Conductance.

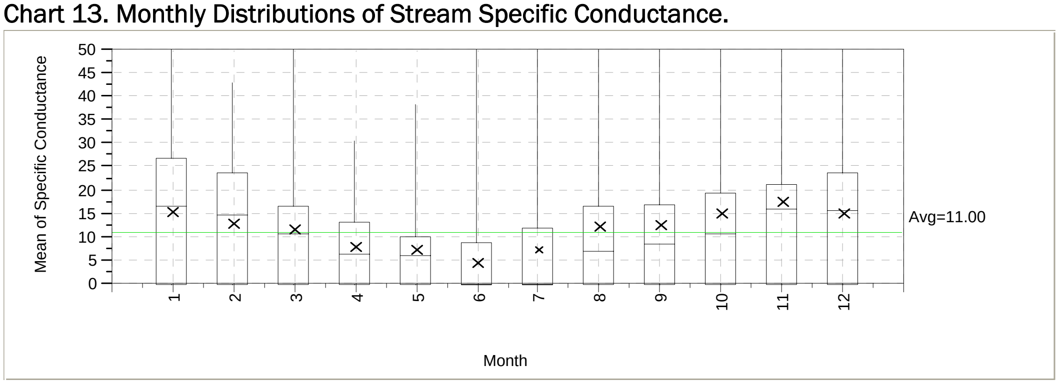
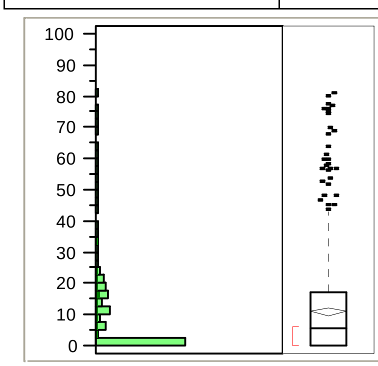


Table 13. Descriptive Statistics: Stream Specific Conductance.

Quantiles		
100.0%	Maximum	81.00
99.5%		77.50
97.5%		60.10
90.0%		27.35
75.0%	3rd Quartile	17.28
50.0%	Median	5.60
25.0%	1st Quartile	0.00
10.0%		0.00
2.5%		0.00
0.5%		0.00
0.0%	Minimum	0.00

Moments	
Mean	11.00
Std Dev	15.48
Std Err Mean	0.64
Upper 95% Mean	12.26
Lower 95% Mean	9.74
N	584



Stream Water Quality: NO_3 (Nitrates)

The sampling program for Nitrates (NO_3) appears to have been flawed as most of the values recorded were zeros. Of the 560 recordings, approximately 90% of the data was recorded as 0, thus raising questions about the authenticity of this data. However, with this potential discrepancy in mind, the average NO_3 was 0.481 with a standard deviation of 3.25. The maximum recorded reading was 32.70.

Chart 14. Monthly Distributions of NO3.

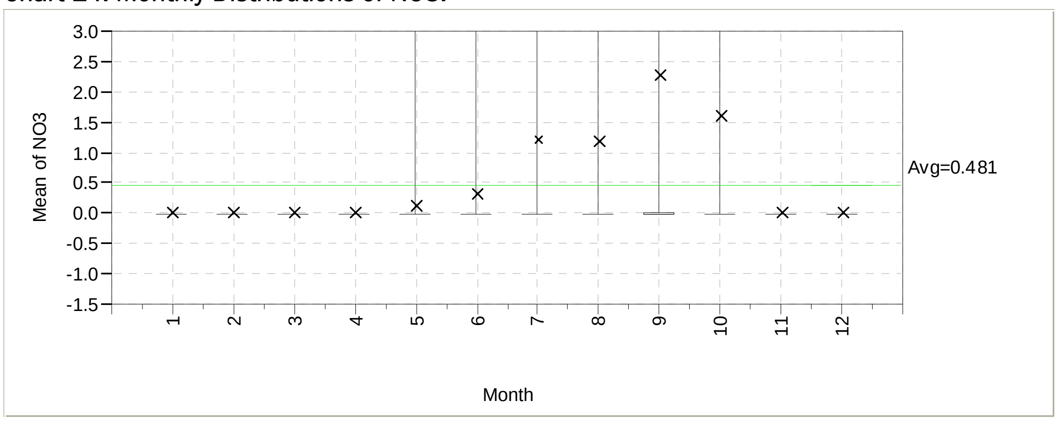
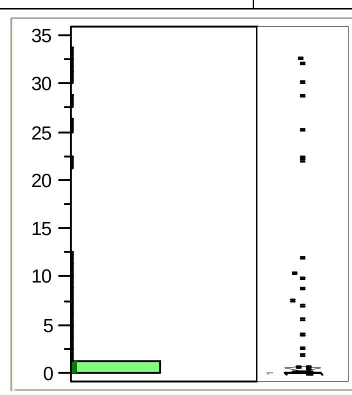


Table 14. Descriptive Statistics: NO3.

Quantiles		
100.0%	Maximum	32.70
99.5%		30.49
97.5%		5.56
90.0%		0.00
75.0%	3rd Quartile	0.00
50.0%	Median	0.00
25.0%	1st Quartile	0.00
10.0%		0.00
2.5%		0.00
0.5%		0.00
0.0%	Minimum	0.00

Moments	
Mean	0.48
Std Dev	3.25
Std Err Mean	0.14
Upper 95% Mean	0.75
Lower 95% Mean	0.21
N	560



Stream Water Quality: Turbidity

Turbidity of the streams for this study was highly variable ranging from a minimum of 0 to a maximum of 1000 NTUs. The average was 49.15 NTUs with a standard deviation of 112.03 NTUs. According to the box plots in Chart 15, the most variable months were May and July. The distribution for turbidity was highly skewed to the right, as observed the histogram below. More that 10% of the turbidity readings exceeded 100 NTUs whereas, 50% of the readings ranged between 4.1 and 31.9 NTUs.

Chart 15. Monthly Distributions of Stream Turbidity.

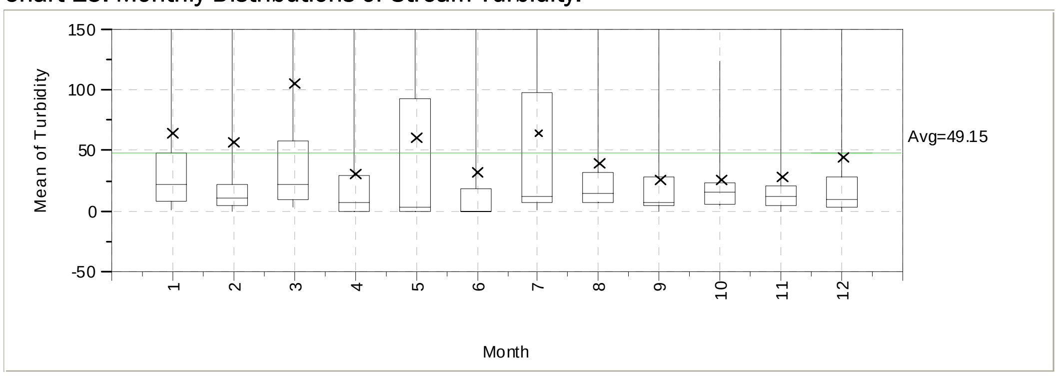
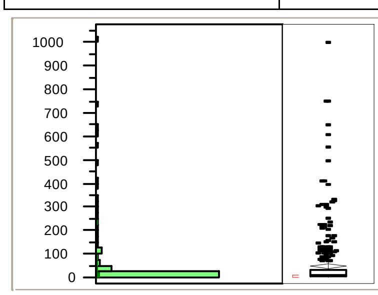


Table 15. Descriptive Statistics: Turbidity.

Quantiles		
100.0%	Maximum	1000.0
99.5%		755.6
97.5%		398.2
90.0%		130.4
75.0%	3rd Quartile	31.9
50.0%	Median	12.1
25.0%	1st Quartile	4.1
10.0%		0.0
2.5%		0.0
0.5%		0.0
0.0%	Minimum	0.0

Moments	
Mean	49.15
Std Dev	112.03
Std Err Mean	5.65
Upper 95% Mean	60.26
Lowerr 95% Mean	38.03
N	393



Ground Water: Water Temperature

Ground water temperature displayed a cyclic trend over time with the lowest readings being observed during the January through June sampling periods and the highest readings being observed during July through December sampling periods. The average water temperature was 18.44 °C with a standard deviation of 1.68°C. The data ranged from a minimum of 14.89 °C to a maximum of 21.45°C. Ninety-five percent of the data fell between 15.73°C and 21.25°C. The histogram indicates that a possible mixture exists and should reflect water temperature regimes at the different sampling locations.

Chart 16. Monthly Distributions of Ground Water Temperatures

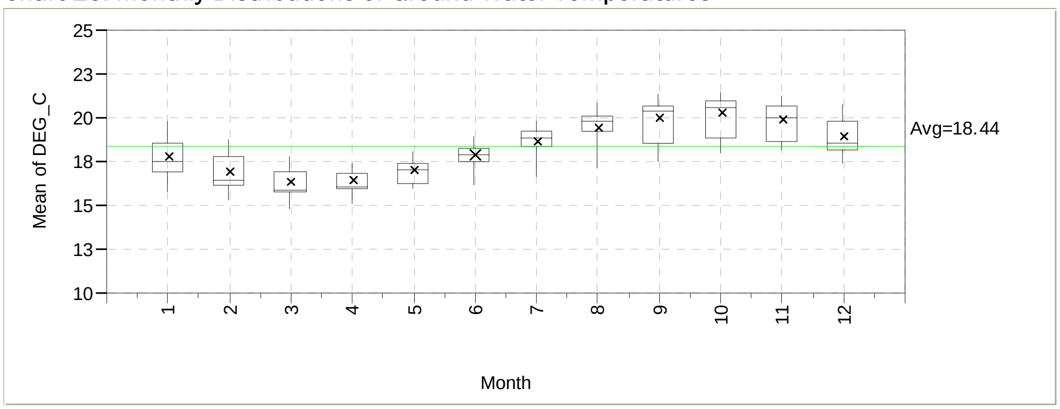
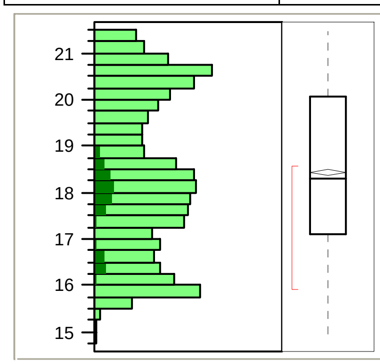


Table 16. Descriptive Statistics: Ground Water Temperatures.

Quantiles		
100.0%	Maximum	21.45
99.5%		21.44
97.5%		21.25
90.0%		20.74
75.0%	3rd Quartile	20.06
50.0%	Median	18.29
25.0%	1st Quartile	17.09
10.0%		16.06
2.5%		15.73
0.5%		15.48
0.0%	Minimum	14.89

Moments	
Mean	18.44
Std Dev	1.69
Std Err Mean	0.03
Upper 95% Mean	18.51
Lower 95% Mean	18.38
N	2,353



Ground Water: Distance from the Top of the Casing to the Water's Surface

The distance from the top of the casing to the surface of the water averaged 3.219 meters with a standard deviation of 0.77 meters. Chart 17 does not reveal any pronounced seasonal trends with this parameter. However, the histogram in Table 17 does show that two distributions are present in the data. This is apparently indicating that there are differences among the sampling locations with respect to this parameter. The minimum distance was recorded as 1.8 meters and a maximum distance of 5.05 meters.

Chart 17. Monthly Distributions of the Distance from the Top of the Casing to the Water's Surface.

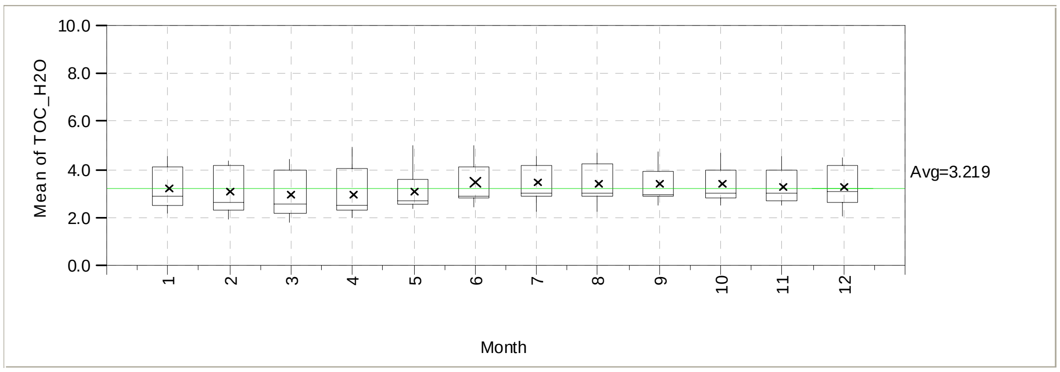
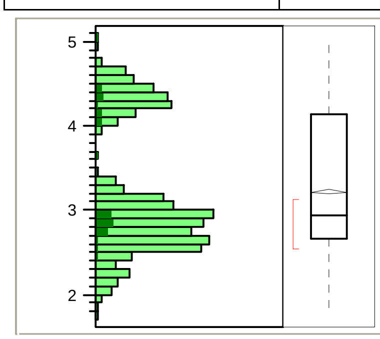


Table 17. Descriptive Statistics: Distance from Top of Casing to Water Surface.

Quantiles		
100.0%	Maximum	5.05
99.5%		4.71
97.5%		4.63
90.0%		4.42
75.0%	3rd Quartile	4.13
50.0%	Median	2.93
25.0%	1st Quartile	2.65
10.0%		2.46
2.5%		2.12
0.5%		1.97
0.0%	Minimum	1.80

Moments	
Mean	3.22
Std Dev	0.77
Std Err Mean	0.02
Upper 95% Mean	3.25
Lower 95% Mean	3.19
N	2,353



Appendix B: SEMP January 2006 Publication Plan

Summary of Publications
JANUARY 2006:

Journal Articles	
Published:	35
Accepted/In Press:	9
Submitted:	19
Books and Book Chapters:	1
Technical Reports	
Published:	30
In Press:	0
Submitted:	4
Theses and Dissertations:	10

CS 1114A – University of Florida and Purdue University – Dr. Reddy (Chapter 4)

Journal Articles

Published

Bhat, S., J.M. Jacobs, K. Hatfield, and J. Prenger. 2006. Ecological indicators in forested watersheds: relationships between watershed characteristics and stream water quality in Fort Benning, GA. Ecological Indicators. 6(2) 458-466.

Bryant, M.L., S. Bhat, and J.M. Jacobs. 2005. Spatiotemporal throughfall characterization of heterogeneous forest communities in the southeastern U.S. Journal of Hydrology. (2005):1-14.

Accepted/In Press

Cohen, M.J., S. Dabral, W.D. Graham, J.P. Prenger, and W.F. DeBusk. Evaluating ecological conditions using soil biogeochemical parameters and near infrared reflectance spectra. Environmental Modeling and Assessment. (Accepted)

DeBusk, W. F., B.L. Skulnick, J.P. Prenger, and K. R. Reddy. 2005. Response of soil organic carbon dynamics to disturbance from military training. Soil and Water Conservation. (In press)

Ogram, A, Hector Castro, E. A. Stanley, Chen, Weiwei, and J. P. Prenger. Distribution of methanotrophs in managed and highly degraded watersheds. Ecological Indicators. (Accepted)

Submitted

Archer, J., and D.L. Miller. Understory vegetation and soil response to silvicultural activity in a southeastern mixed pine forest: a chronosequence study. Journal of Forest Ecology and Management. (Submitted January 2004)

Bhat, S., K. Hatfield, J.M. Jacobs, R. Lowrance, and R. Williams. Prediction of nitrogen leaching from freshly fallen leaves: application of Riparian Ecosystem Management Model (REMM). Journal of Hydrology. (Submitted February 2006)

Bhat, S., J.M. Jacobs, K. Hatfield, and W. Graham. Hydrological indicieds of watershed scale military impacts in Fort Benning, GA. Journal of Hydrology. (Submitted September 2004)

Dabral, S., W.D. Graham, and J.P. Prenger. Quantitative analysis of soil nutrient concentrations with near infrared spectroscopy and partial least squares regression. Soil Science Society of America Journal. (Submitted March 2004)

Perkins, D., N. Haws, B.S. Das, and S. Rao. Soil hydraulic properties as indicators of land quality for upland soils in forested watersheds with military training impacts. Journal of Environmental Quality. (Submitted March 2004)

Perkins, D., N. Haws, S. Rao, J. Jawitz. Hydraulic conductivity of upland soils in forested watersheds at Fort Benning, GA: assessment of mechanized military training. Vadose Zone Journal. (Submitted April 2004)

Prenger, J.P., W.F. DeBusk, and K.R. Reddy. Influence of military land management on extracellular soil enzymes. Soil Biology and Biochemistry. (Submitted December 2004)

Prenger, J.P., Bhat, S., J.M. Jacobs, and K. R. Reddy. Microbial nutrient cycling in the riparian zone of a coastal plain stream. Journal of Environmental Quality. (Submitted March 2004)

Silveira, M.L., B. Skulnick, W.F. DeBusk, J. Prenger, N.B. Comerford, and K.R. Reddy. In situ and laboratory soil CO2 efflux related to military training disturbance in a southern Georgia landscape. Soil Biology and Biochemistry. (Submitted December 2004)

Tanner, G.W. and D.L. Miller. Vegetative indicators of disturbance in a chronically-disturbed ecosystem, Ft. Benning Army Reservation, Georgia. Ecological Restoration. (Submitted April 2004)

Technical Reports

Reddy, R., J. Prenger, W. DeBusk, W. Graham, J. Jacobs, A. Ogram, D. Miller, S. Rao, and G. Tanner. 2004. Determination of Indicators of Ecological Change Project Final Report. University of Florida IFAS.

Theses and Dissertations

Archer, J.K. 2003. Understory vegetation and soil response to silvicultural activity in a southeastern mixed pine forest: a chronosequence study. M.S. Thesis. University of Florida.

Bryant, M.L. 2002 Spatiotemporal throughfall characterization of heterogeneous forest communities in the southeastern U.S. M.S. Thesis. University of Florida

Chen, W. 2001. Optimization of terminal restriction fragment length polymorphism and evaluation of microbial community structure as indicator of ecosystem integrity. M.S. Thesis. University of Florida.

Perkins, D. 2003. Soil hydrologic characterization and soil-water storage dynamics in a forested watershed. M.S. Thesis. Purdue University.

Skulnick, B.L. 2002. Soil carbon biogeochemistry: indicators of ecological disturbance. M.S. Thesis. University of Florida.

Tkaczyk, M. 2002. Rainfall runoff and subsurface flow analysis to investigate the flow paths in forested watersheds utilizing TOPMODEL. M.S. Thesis. University of Illinois at Chicago.

CS 1114B – Prescott College – Dr. Krzysik (Chapter 5)

Journal Articles

Published

Duda, J.J., D.C. Freeman, M.L. Brown, J.H. Graham, A.J. Krzysik, J.M. Emlen, J.C. Zak, and D.A. Kovacic. 2003. Estimating disturbance effects from military training using developmental instability and physiological measures of plant stress. Ecological Indicators 3:251-262.

Freeman, D.C., M.L. Brown, J.J. Duda, J.H. Graham, J.M. Emlen, A.J. Krzysik, H.E. Balbach, D.A. Kovacic, and J.C. Zak. 2004. Developmental instability in Rhus copallinum L.: multiple stressors, years, and responses. International Journal of Plant Sciences. 165(1):53-63.

Freeman, D.C., M.L. Brown, J.J. Duda, J.H. Graham, J.M. Emlen, A.J. Krzysik, H.E. Balbach, D.A. Kovacic, and J.C. Zak. 2004. Photosynthesis and fluctuating asymmetry as indicators of plant response to soil disturbance in the Fall Line Sandhills of Georgia: a case study using Rhus copallinum and Ipomoea pandurata. International Journal of Plant Sciences. 165(5): 805-816.

Freeman, D.C., M.L. Brown, J.J. Duda, J.H. Graham, J.M. Emlen, A.J. Krzysik, H.E. Balbach, D.A. Kovacic, and J.C. Zak. 2005. Leaf fluctuating asymmetry, soil disturbance and plant stress: a multiple year comparison using two herbs, Ipomoea pandurata and Cnidoscolus stimulosus. Ecological Indicators 5:85–95.

Graham, J.H., H.H. Hoyt, S. Jones, K. Wrinn, A.J. Krzysik, J.D. Duda, C.D. Freeman, J.M. Emlem, J.C. Zak, D.A. Kovacic, C. Chamberlin-Graham, and H.E. Balbach. 2004. Habitat disturbance and the diversity and abundance of ants (Formicidae) in the Fall-Line Sandhills of Georgia. Journal of Insect Science. 4:15-30.

Sobek, E.A., and J.C. Zak. 2003. The soil FungiLog procedure: methods and analytical approaches towards understanding fungal functional diversity. Mycologia 95:590-602.

Submitted

Freeman, D.C., M.L. Brown, J.J. Duda, S. Kitchen, J.M. Emlen, J.H. Graham, J. Malol, E. Bankstahl, A.J. Krzysik, H.E. Balbach, D.A. Kovacic, and J.C. Zak. A multiple year study of the influence of disturbance and prescribed fires on the growth and development instability of loblolly pine (Pinus taeda) in the Fall-Line Sandhills of Georgia. Oecologia. (Submitted April 2005) (In Revision March 2006)

Graham, J.H., A.J. Krzysik, D.A. Kovacic, J.J. Duda, D.C. Freeman, J.M. Emlen, J.C. Zak, W.R. Long, M.P. Wallace, C. Chamberlin-Graham, J. Nutter, and H.E. Balbach. Intermediate disturbance and ant communities in a forested ecosystem. Diversity and Distributions. (Submitted December 2005)

Kovacic, D.A., A.J. Krzysik, M.P. Wallace, J.C. Zak, D.C. Freeman, J.H. Graham, H.E. Balbach, J.J. Duda, and J.M. Emlen. Soil mineralization potential as an ecological indicator of forest disturbance. Ecological Indicators or Biology and Fertility of Soils (Submitted March 2006).

Technical Reports

Submitted

Krzysik, A.J., and H.E. Balbach. Development of a Site Condition Index: Southeast Upland Forests Draft Technical Report. (Submitted September 2004)

Krzysik, A.J., H.E. Balbach, J.J. Duda, J.M. Emlen, D.C. Freeman, J.H. Graham, D.A. Kovacic, L.M. Smith, and J.C. Zak. Development of Ecological Indicator Guilds for Land Management. Draft Final SERDP Technical Report. (Submitted April 2005)

CS 1114C – ORNL – Dr. Dale (Chapter 6)

Journal Articles

Published

Black, B.A., H.T. Foster, and M.D. Abrams. 2002. Combining environmentally dependent and independent analysis of witness tree data in east-central Alabama. Canadian Journal of Forest Research 32:2060-2075.

Dale, V.H., and S.C. Beyeler. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators 1:3-10.

Dale, V.H., S.C. Beyeler, and B. Jackson. 2002. Understory indicators of anthropogenic disturbance in longleaf pine forests at Fort Benning, Georgia, USA. Ecological Indicators 1(3):155-170.

Dale, V.H., D. Druckenbrod, L. Baskaran, M. Aldridge, M. Berry, C. Garten, L. Olsen, R. Efroymson, and R. Washington-Allen. 2005. Vehicle impacts on the environment at different spatial scales: observations in west-central Georgia. Journal of Terramechanics. 42:383-402.

Dale, V.H., D. Druckenbrod, L. Baskaran, C. Garten,L. Olsen, R. Efroymson, R. Washington-Allen, M. Aldridge, and M. Berry. 2005. Analyzing land-use change at different scales in central Georgia. Proceedings of the 4th Southern Forestry and Natural Resource GIS conference. Athens, Georgia, Dec 16-18, 2004.

Dale, V.H., S. Archer, M. Chang, and D. Ojima. 2005. Ecological impacts and mitigation strategies for rural land management. Ecological Applications. 15(6): 1879-1892.

Dale, V.H., M. Aldridge, T. Arthur, L. Baskaran, M. Berry, M. Chang, R. Efroymson, C. Garten, C. Stewart, and R. Washington. 2006. Bioregional Planning in Central Georgia, USA. Futures 38(4): 471-489

Houser, J.N., Mulholland, P.J., and K.O. Maloney. 2005. Catchment disturbance and stream metabolism: patterns in ecosystem respiration and gross primary production along a gradient of upland soil and vegetation disturbance. North American Benthological Society. 24(3):538-552.

Houser, J.N., P.J. Mulholland, and K. Maloney. 2006. Upland Disturbance Affects Headwater Stream Nutrients and Suspended Sediments during Baseflow and Stormflow. Journal of Environmental Quality. 35:352-365.

Maloney, K.O., and J.W. Feminella. 2006. Evaluation of single- and multi-metric benthic macroinvertebrate indicators of catchment disturbance at the Fort Benning Military Installation, Georgia, USA. Ecological Indicators. 6:469-484.

Maloney, K.O., P.J. Mulholland, and J.W. Feminella. 2005. Influence of catchment-scale military land use on physicochemical conditions in small Southeastern Plains streams (USA). Environmental Management. 35: 677-691.

Mulholland, P.J., J.N. Houser, and K.O. Maloney. 2005. Stream diurnal dissolved oxygen profiles as indicators of in-stream metabolism and disturbance effects: Fort Benning as a case study. Ecological Indicators. 5: 243-252.

Olsen, L.M., Washington-Allen, R.A, and V.H. Dale. 2005. Time-series analysis of land cover using landscape metrics. GIScience and Remote Sensing 42(3).

Peacock, A.D., S.J. MacNaughton, J.M. Cantu, V.H. Dale, and D.C. White. 2001. Soil microbial biomass and community composition along an anthropogenic disturbance gradient within a longleaf pine habitat. Ecological Indicators 1(2):113-121.

Theobald, D.M., T. Spies, J. Kline, B. Maxwell, N.T. Hobbs, and V.H. Dale. 2005. Ecological support for rural land-use planning and policy. Ecological Applications. 15(6): 1906-1914.

Accepted/In Press

Dale, V.H., Peacock, A., C. Garten, and E. Sobek. Contributions of soil, microbial, and plant indicators to land management of Georgia pine forests. Ecological Indicators. (Accepted with revisions)

Maloney, K.O., R.M. Mitchell, and J.W. Feminella. Influence of catchment disturbance on fish integrity in low-diversity headwater streams. Southeastern Naturalist. (In Press)

Olsen, L.M., V.H. Dale, and H.T. Foster. Landscape patterns as indicators of ecological change at Fort Benning, GA. Land Use and Urban Planning. (In press)

Submitted

Druckenbrod, D.L., and V.H. Dale. Experimental response of understory plants to mechanized disturbance in an oak-pine forest. Ecological Applications. (Submitted July 2005)

Wolfe, A., and V.H. Dale. A. Using a Delphi approach to negotiate a common framework within which to integrate science and practice. Journal of Environmental Management. (Revised +Submitted March 2006)

Technical Reports

Dale, V.H. et al. 2004. Indicators of Ecological Change Project Final Report. Oak Ridge National Laboratory, TN.

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Beyeler, S.C. 2000. Ecological indicators. Master's Thesis. University of Miami in Ohio.

Foster, H.T., II. 2001. Long term average rate maximization of Creek Indian residential mobility a test of the marginal value theorem. Ph.D. Dissertation. Department of Anthropology, Pennsylvania State University.

Maloney, K. 2004. Ph.D. dissertation. Auburn University, Alabama. (Awarded The Carolyn Taylor Carr Outstanding Award Dissertation for 2004-2005 from the Auburn Chapter of Sigma Xi).

Book Chapter

Dale, V.H., P. Mulholland, L.M. Olsen, J. Feminella, K. Maloney, D.C. White, A. Peacock, and T. Foster. 2004. Selecting a Suite of Ecological Indicators for Resource Management, Landscape Ecology and Wildlife Habitat Evaluation: Critical Information for Ecological Risk Assessment, Land-Use Management Activities and Biodiversity Enhancement Practices. ASTM STP 11813, L.A. Kapustka, H. Gilbraith, M. Luxon, and G.R. Biddinger, Eds. ASTM International, West Conshohocken, PA.

CS 1114D – ORNL – Mr. Garten (Chapter 7)

Journal Articles

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Appendix C: SEMP-Associated Project:

(SERDP Project Fact Sheet – www.serdp.org/Research/upload/CS_FS_1462.pdf)

REVISED 12/28/05

Developing a Spatially Distributed Terrestrial Biogeochemical Cycle Modeling System to Support the Management of Fort Benning and its Surrounding Areas

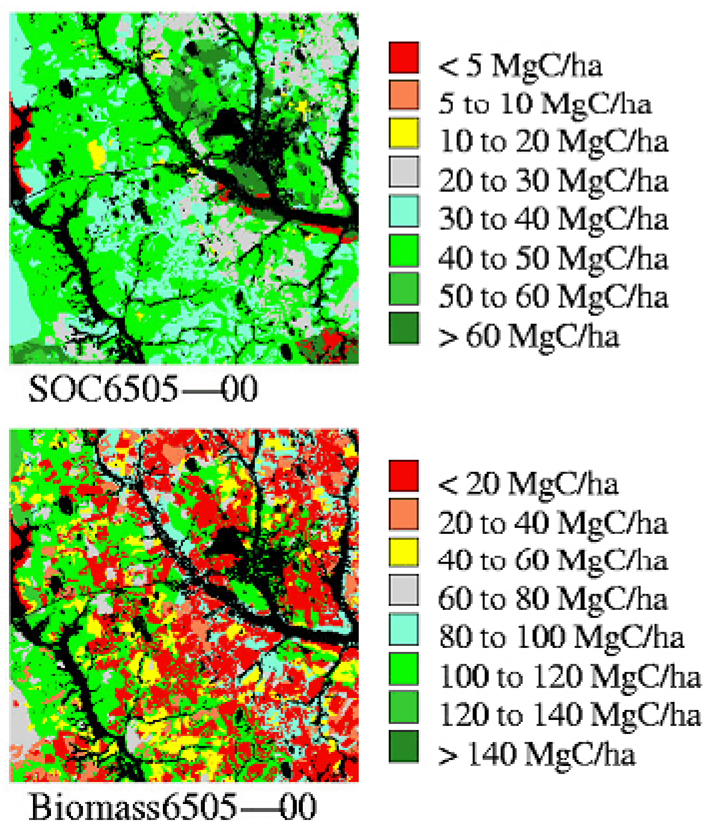
Conservation CS-1462

Biogeochemical cycles describe the movement of nutrients, matter, and elements between the earth's systems and influence a variety of biological, geological, and chemical processes. Well-designed models predicting fluctuations in the biogeochemical cycles of carbon (C) and nitrogen (N) can provide valuable information on the impacts of land management and uses, climate change and variability, and other ecosystem processes dependent on those cycles.

Current models are limited by the scale to which they can accurately predict changes in these cycles. Relating them to land use and management on a regional scale and taking into account on-installation land practices is a challenge.

Objective:

The objective of this project is to develop an advanced, spatially distributed, terrestrial biogeochemical cycle modeling system for Fort Benning, Georgia, and its surrounding ecosystems. This system will contribute to an overall understand-



Spatially explicit modeling of carbon stocks in soils (SOC) and vegetation (biomass) in 2000 in a 10-km by 10-km block (ID: 6505) in the vicinity of Fort Benning, Georgia. Impacts of soil erosion and deposition were not included.

ing of ecosystem dynamics and enable development of nutrient availability thresholds.

Process/Technology Description:

This research will be conducted in two phases. In the first phase, a conceptual modeling system consisting of a plot-scale and a regional-scale model of both C and N cycles will be developed. The system will address the impacts of natural processes and land management practices on C and N cycle dynamics for ecosystems on and around Fort Benning. The conceptual modeling system will modify and expand upon existing biogeochemical models in order to leverage existing biogeochemical research at Fort Benning. In the second phase, the conceptual modeling system will be implemented numerically, using model parameters and driving variables derived from existing Fort Benning research activities. Due to the spatially explicit simulations of soil C and N movements on the landscape, the modeling system will be capable of operating at a range of spatial scales in terrestrial, riparian, and aquatic contexts.

Expected Benefits:

This modeling system will provide installation managers with valuable information describing the biogeochemical responses of Fort Benning's ecosystems. Installation managers then can apply that information toward improving their land use and management activities, including restoration of longleaf pine forests, prescribed fire regimes, and rehabilitation of lands and waterways for sustained military use. Furthermore, this modeling system will be developed in such a way that it can be readily adapted to simulate C and N cycles in other geographical regions. (Anticipated Project Completion - 2008)

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Appendix D: New FY07 SEMP- Associated Project

SON NUMBER: SISON-07-04 10 November 2005
STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM
STATEMENT OF NEED FOR FY 07
SUSTAINABLE INFRASTRUCTURE NEW START
WATERSHED MANAGEMENT MODELS FOR MILITARY INSTALLATIONS: FORT BENNING WATERSHEDS

1. OBJECTIVES OF THE PROPOSED WORK

The objective of this Statement of Need (SON) is to identify, adapt, and develop, as needed, watershed management models that address interactions of watershed hydrology with military land management activities, natural resources management, and related ecosystem processes and outcomes. Proposed work should result in a prototype operational modeling system designed and calibrated for Fort Benning but transferable to other installations.

The prototype system should address (but not limited to) the following issues: erosion/sedimentation, nutrient loadings, and aquatic ecosystem responses from activities such as construction and use of training areas, live fire ranges, roads, housing and building complexes, forestry management (including prescribed burning), and related pollutant loadings. The proposal should describe modeling and analysis techniques for both forecasting in support of management actions and "back calculating" from monitored physical, chemical, and biological data to assess causes of observed water quality issues. The proposed modeling system should enable military installations to fully evaluate and enhance watershed management programs designed to meet the goals of the Federal Clean Water Act, as amended (including the wetland protection provisions of that Act). While other watershed hydrology related issues pertinent to military installations are acknowledged, (for example ground water supplies for drinking purposes) the priority context for this solicitation are the goals of the Clean Water Act.

The modeling system should include all hydrological processes sufficient to provide detailed, spatially appropriate, and dynamic water balances for military installations. Water balances for a wide array of flow regimes are desirable. The proposed time and spatial scales for these processes are at the discretion of the proposer but the proposal is expected to highlight the expected interface needs for military training, ecological, and land management activities. Information expressed in GIS data layers must be accommodated within the model.

2. EXPECTED PAYOFF OF PROPOSED WORK

Ecosystem management to provide for sustained and future sustainable mission capacity remains the DoD policy for military installations including Fort Benning. The ecosystem management expectation can only be met by providing the tools necessary to actively manage watersheds. Water quality and related aquatic ecosystems are major endpoints and are insufficiently understood components of natural resource management, particularly for military installations. Fort Benning and other installations should be provided with immediately usable and effective models that can be implemented for compliance as well as long-term watershed planning and management.

3. BACKGROUND

Research on hydrologic and watershed process models, particularly for processes and applications reflecting climate change concerns and the related temporal and large spatial scales has progressed with demonstrated coupling of hydrology and ecosystem sciences. At much smaller scales, modeling as part of watershed management to meet water quality goals is not new but most current models were developed and tested two decades ago. Models that reflect hydrologic and aquatic impacts from military conditions are rare. Watershed and hydrologic – ecosystem models that enable diagnostic, predictive, and operational applications in conjunction with monitoring and data collection programs are virtually non-existent across-the board and are urgently needed within the scientific and modeling communities. The ability to both forecast outcomes and “back calculate” the likely causes from observations is needed to fully inform policy and management options.

In 1997, the SERDP Program Office initiated a focused examination of ecosystem management as an area of research relevant to the sustainability of military land and water resources within the context of sustaining mission requirements. Accordingly, in 1999, the SERDP Ecosystem Management Program (SEMP) was launched at Fort Benning. Recently the SEMP program has undergone a strategic shift. A Strategic Planning Workshop held near Fort Benning identified, inter alia, watershed management as an urgent need. Subsequently the SEMP program updated the science strategy and this SON is part of that new thrust. This information is available for review at:
https://sempdata.erdc.usace.army.mil/serdp/watershed/

The relationship of land and watershed uses and management to aquatic and hydrologic responses, both on and off the military installation, are key factors in the proposed work. On-installation land use and management activities include a range of differing 1) military mission requirements (e.g., changes in training load, and introduction of new equipment and weapons systems), 2) construction to accommodate increases in base personnel, 3) forestry practices, 4) ecosystem management goals (e.g., restoring long leaf pine forests, protecting riparian and wetland zones), and 5) construction and operations to accommodate shifts in training regimes, equipment, and tactics. Off-installation land uses include urban development, agriculture, and commercial forestry. Watershed delineations, available climate and hydrologic data, current and historical land use and land cover data, and ongoing or proposed construction areas are also available, in part, at the following website: https://sempdata.erdc.usace.army.mil/serdp/watershed/

The demands and needs for hydrologic and watershed management models are increasing as military activities increase within watershed boundaries. Management needs include assistance in diagnosing problems from monitoring data, predicting responses from alternative remedies, and in evaluating operational approaches. An example of a diagnostic modeling application is identifying the sources, pathways, and land disturbance activities that most likely caused an observed water quality problem. An example of a predictive modeling application is evaluating the hydrologic and water quality impacts from alternative locations and designs for land management activity (e.g., construction firing range or maneuver training site). An example of an operational modeling application is evaluating the hydrologic and water quality impact of existing land management activity (e.g., firing or maneuver training site) and identifying operational techniques to reduce impacts, reduce costs of mitigation and maintenance schedules, or otherwise optimize operational procedures. Water balance modeling includes the prediction of surface runoff, stream flows, soil moisture, evapotranspiration, wetland and reservoir inflows/outflows, storm and combined sewer flows, and subsurface flows including water table dynamics(as needed to meet computational requirements for surface water processes).

4. COST AND DURATION OF PROPOSED WORK

The cost and time to meet the requirements of this SON are at the discretion of the proposer. The proposer should incorporate the appropriate time schedule and cost requirements to accomplish the scope of work proposed. SERDP staff will evaluate the cost and duration of the project plan in light of the scope of work proposed. SERDP projects normally run from 2 to 4 years in length and vary considerably in cost consistent with the scope of the effort. Proposers are encouraged to and may submit smaller proposals that offer technical or cost advantages that only address one or more portions of the SON.
Proposers with innovative approaches to the SON, that entail high technical risk and/or have minimal supporting data, may submit a pre-proposal for a limited amount of funding (less than $100,000 for a single year) to develop the data necessary to provide for risk reduction and/or a proof of concept. Such proposals, if successful, may be eligible for follow-on funding. These pre-proposals are due on January 5, 2006, the same date as pre-proposals (for BAA responders) or on the date requested by the federal member's organization (for federal responders).
The government reserves the right to fund more than one proposal either to meet this requirement fully or to pursue more than one innovative approach.

5. POINT OF CONTACT

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For proposal submission instructions and additional solicitation information, visit the Funding & Opportunities page on the SERDP web site:
http://www.serdp.org/funding

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY) March 2007

2. REPORT TYPE Final

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE
SERDP Ecosystem Management Project (SEMP)
2005 Annual Report

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Compiled by Harold E. Balbach and Elizabeth L. Keane

5d. PROJECT NUMBER
SI-1114 (formerly CS)

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC SR-07-2

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Strategic Environmental Research and Development Program
901 N. Stuart St., Suite 303
Arlington, VA 22203

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

The SERDP Ecosystem Management Project (SEMP) was initiated in 1998 by the Strategic Environmental Research and Development Program (SERDP), after a 1997 workshop on Department of Defense ecosystem management challenges. After the workshop, SERDP allocated initial funding to a new project, titled the SERDP Ecosystem Management Project, designated as CS-1114, which changed in mid-2005 to SI-1114. This report records the many changes that occurred in the SEMP Project in the year 2005. All the original SEMP research projects have completed their funded work and final reports were received during this year. As reported in the 2004 SEMP annual Report, significant change took place in almost every aspect of SEMP program management and execution during 2005. The response to the comprehensive external review of SEMP is reported as these changes have been implemented. New SEMP research projects are no longer being funded within the SEMP budget, but will be separate Statements of Need through the normal SERDP process. Two workshops were held at Fort Benning in January and February 2005 to identify more critical installation needs; Fort Benning staff, SEMP researchers, TAC members, and several outside experts reviewed these results, which resulted in a redefined research plan for 2006 and beyond.

15. SUBJECT TERMS
Strategic Environmental Research and Development Program (SERDP) environmental planning land management
ecosystem management SERDP Ecosystem Management Program (SEMP)

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Harold E. Balbach
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	SAR	191	(217) 352-6511, ext 6785